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THE ELEMENTS
OF THE
ANATOMY AND PHYSIOLOGY OF MAN.



THE ELEMENTS
OF
ANATOMY AND PHYSIOLOGY OF MAN.

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THE ELEMENTS
OF THE
ANATOMY AND PHYSIOLOGY
OF MAN.

A TEXT-BOOK FOR STUDENTS AND SCHOOLS.

BY
G. G. P. BALE, M.A.
ST. JOHN'S COLLEGE, CAMBRIDGE.

STUDENTS' EDITION.



REMINGTON AND CO.
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1879.

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165 . e . 84 .

Dedicated to
THE. REV. T. G. BONNEY, B.D., F.R.S., ETC.,
FELLOW AND LATE TUTOR OF ST. JOHN'S COLLEGE, CAMBRIDGE,
IN ADMIRATION OF
HIS SCIENTIFIC AND OTHER ATTAINMENTS,
AND IN GRATEFUL RECOLLECTION OF
MANY ACTS OF KINDNESS SHOWN TO
HIS FORMER PUPIL,
THE AUTHOR.

PREFACE.

THE aim of this small work is to give, with the greatest brevity consistent with clearness, as much of the elements of Human Anatomy and Physiology as would present to the early student a fairly accurate reflection of the exact state of this field of science, abounding, as it yet does, with conflict of evidence and of authority.

After searching, as a student, amongst the various hand-books in common use, and finding them very incomplete, and containing many hereditarily-transmitted errors and descriptions of obsolete experiments, I felt compelled to have recourse to the writings of such original authorities as were available, supplementing them with a few experiments. Whilst enjoying a spring of convalescence upon the Riviera, I determined, by way of beguiling the occasional tedium of too many leisure hours, to systematize some of the more reliable *matériel* I had then obtained (which attempt I afterwards determined to publish). I think it but just to state this, inasmuch as (the MSS. being written during the months of March and April, 1876) the work is not indebted to the several excellent treatises on Physiology, since published, excepting for a *few* of the recent discoveries lately incorporated. Up to the present time, there has not existed any elementary scientific *précis* (in the English language) of Anatomy, Histology, or Embryology, and but one very elementary (scientific) one, which combines in a single volume both Anatomy and Physiology; whilst the works on Physiology, above alluded to, are of such magnitude, and *most* of them so full of bewildering detail as to render them nearly useless for schools;—hence the *raison-d'être* of this work. This consideration has also induced me to avoid

crowding the pages with the names of authorities, and, any more than was necessary, with the isolated facts of that complicate, yet rudimentary science—Animal Chemistry.

I have devoted considerable attention to illustration, in order that the work might be equally serviceable to schools and students; otherwise, owing to its brevity (about 170 pages of letter-press) and technicality, it would have incurred the peril of being relegated to the objectionable status of a 'cram-book' for the latter class. Most of the illustrations were prepared by myself, and this must be my apology for any want of artistic effect: many will be recognized as old friends corrected (acknowledged as being *after* the originals); the remaining ones are either from Nature, or are semi-diagrammatic: a few were the production of a professional artist. These original illustrations were engraved for me by the Typo-Etching Company,—the remainder of the blocks (excepting Kölliker's) being kindly lent by various publishers, to whom I beg to express my sincere obligations: to the New Sydenham Society for figs. 66, 70, 137, 187, 198, 199, taken from Stricker's Histology; to Messrs. Baillière and Tyndall for figs. 69, 188, 420, from the Anatomie Descriptive par MM. Beaunis et Bouchard; and to Messrs. Bell and Daldy for figs. 207, 252, 253, from Agassiz and Gould's Comparative Physiology.

This work has also been published in an abridged form, omitting the chapter on Reproduction, &c., for use in those schools, where the omission may be deemed desirable. I feel it, however, to be my duty to enter a protest against the Manichæan spirit which *usually* prompts the infelicitous consignment of sexual matters to the realms of mystery. For a somewhat similar reason I have excised from both editions the paragraphs originally written upon Brain Physiology. It need hardly be remarked that cell-measurements, details which only occur in figure descriptions, &c., are preferably disregarded by first beginners.

G. G. P. BALE.

March, 1879.

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A TEXT-BOOK

OF THE

ANATOMY AND PHYSIOLOGY OF MAN.

CHAPTER I.

ANIMAL CHEMISTRY AND HISTOLOGY.

1. The fourteen Ultimate Elements of the Human body are—

	lbs.	oz.		oz.	gr.
Oxygen	100	—	Chlorine	2	—
Carbon	19	—	Fluorine	2	—
Hydrogen	13	—	Potassium	—	260
Nitrogen	3	8	Iron	—	100
Calcium	2	—	Magnesium	—	12
Phosphorus	1	12	Silicon	—	2
Sulphur	—	3			
Sodium	—	2			

Total about 140 lbs.

Sometimes minute quantities of other elements are found, e.g. manganese rather frequently. The gaseous elements are found in a state of combination : in the blood and the various fluid secretions, however, three (and only three) gases are found free, in varying quantity. These are carbonic acid,* oxygen, and nitrogen—the first predominating, the last always in very small quantities. The body contains 59½ per cent. or 82 lbs. of water,† the quantity varying from 2 per 1000 in the enamel to 827 in renal tissue.

2. The respective weights of the tissues are about as follows :—Muscle, 68 lbs.; bones, 21 ; skin, adipose, and con-

* I have preferred retaining the term “carbonic acid,” although CO² would be more correctly called carbon-dioxide or carbonic anhydride.

† Water consists of oxygen and hydrogen (H² O).

nective tissue, 20 ; blood and lymph, 14 ; brain and viscera, 17. The specific gravity of the body is 1·065. The weight of the body varies with the height to a considerable degree—about 5 lbs. per inch. Temperature—health—season of the year, &c., also affect the weight. Without clothes, an average adult Englishman is 5ft. 6½in.—5ft. 7in. in height, and weighs 140 lbs. (to 144 lbs.): woman about 5ft. 3in., and 120 lbs.

3. Life is kept up by means of a kind of combustion going on throughout the whole body—this is due to the process of oxidization. To supply this waste, there must be something taken into the body—food. Food may be looked upon as principally of two kinds: (1) Nitrogenous, azotized, plastic, or flesh-forming; and (2) non-azotized, carbonaceous, respiratory, or heat-forming: the former consisting chiefly of oxygen, hydrogen, carbon, and nitrogen in various proportions; the latter being devoid of nitrogen (azote), (and of sulphur). Proximate principles are those combinations to which all food may be reduced without absolute disintegration into elements. The average composition of albuminoid compounds is C 54, H 7, N 16, O 21·5 sulphur (usually present) 1·5, the gelatinous ones might well be considered as extractives. The more important azotized proximate principles are:—

1. PROTEINACEOUS OR ALBUMINOID.

- { Albumen (animal origin) resembles white of egg.
- { Gluten (vegetable origin).
- Fibrin (v. [a. P]).
- { Casein (a.) cheese.
- { Legumen (v.).
- Vitelline (a.).
- Globulin (a.) albuminous constituent of red blood-corpuscles.
- Hæmatin (a.) their colouring principle, containing much iron.
- Syntonin (a.) coagulated myosin.
- "Extractive matters" (a.) various active principles, e.g., pepsin, mucin, &c., elastin (from yellow fibre), keratin (horny tissues, as epidermis, nails, hair, &c.), and others. Some not defined.

2. GELATINOUS.

- Gelatin (a.) is obtained by boiling bone, white fibre, and fibro-cartilage.
- Chondrin (a.) by boiling true cartilage.

Non-azotized proximate principles are of two kinds: *Hydro-carbons*, or fatty substances in which the oxygen is very deficient in quantity, and *Carbo-hydrates*, amyloid, or starchy substances. The carbo-hydrates [$C^{62} (H^2 O)^7$] are:—

Starch, v. ($C^{12} H^{20} O^{10}$).	Gum, v. ($C^{12} H^{22} O^{11}$).
Cane Sugar, v. ($C^{12} H^{22} O^{11}$).	Dextrine, a. (artificial, $C^{12} H^{20} O^{10}$).
Grape Sugar or Glycose, v. ($C^{12} H^{24} O^{12}$).	Cellulose, v.
Lactin (sugar of milk), a.	Lignine, v.
Inosite (muscle sugar), a.	Lactic acid ($C^{12} H^{24} O^{12}$).
Amyloid substance (Glycogen), a.	Acetic acid.

(The formulæ have been purposely reduced to a common measure.)

The hydro-carbons are oils (v. a.) and fats (a.) They consist chiefly of an admixture of palmitine, stearine, and olein: the two former predominating in butter and fats, the last in oils. The average of human fats may be empirically expressed thus, $C^{62} H^{99} O^6$. Inorganic elements used as food are water, salts, &c. Some medicines are really food.

4. The greater part of the nitrogenous substances supply the formation of the tissues and secretions,—a little also going to form heat: the non-nitrogenous substances supply heat (and force) only. The calorific power of fat is twice as great as that of starch and sugar (of dry fat $2\frac{1}{2}$ times) and one part of dry fat = $7\frac{7}{10}$ of lean flesh. The amount of food required varies chiefly according to the amount of *exercise* taken. There is a pretty definite ratio between the excess of food and the amount of work performed, within certain limits. If the excess be not used, there is a tendency to store it up as flesh and *fat*. Children require more food than adults (proportionally), and persons in cold climates more than those in warm, especially of fatty substances. From $2\frac{1}{2}$ —6 oz. of nitrogenous food, and 19—35 oz. of carbonaceous (of the value of starch), are the usual limits.

	oz. of Ns.	Cs.	gr. of C.	N.
At rest . . .	2·67	19·61	containing 3816	180
Ordinary labour	4·56	29·24	„ 5688	307
Active labour .	5·81	34·97	„ 6823	391

The nitrogenous is in proportion to the carbonaceous as 1 : 6.

Raising the temperature of 1 lb. of water 1° F. produces a force equal to lifting 772 lbs. one foot high, that is = 772 foot-pounds. The oxidization or combustion of carbon and hydrogen evolve a great amount of heat,—on subsistence diet equivalent to 8,256,486 ft.-lbs. on working diet to 10,874,136 ft.-lbs. The daily *force* exerted is calculated at 7,720,000 ft.-lbs (all food taken not being used) : of this 1,011,670 are used in active mechanical labour (taking about 40,000 to walk a mile), 500,040 in circulation (at 75), 98,496 in respiration (at 15), total of muscular movements 1,610,206, the rest being consumed in molecular movements. Viewed externally, the *heat* is thus disposed of:—

In raising temperature of food	2.6 per cent.
„ of air respired	5.2 „
Vaporizing water from lungs	14.7 „
Radiation from body, and perspiration	77.5 „

The temperature of the body is always uniform, and is about 98.8° F. ($97-99\frac{1}{2}$) ; may vary in disease from $77-112\frac{1}{2}$. The temperature is about the same in summer as in winter ; for although much more heat is lost in the former by perspiration, much more is lost in the latter by radiation (from the surface of the body) : the skin is thus the great immediate agent in the regulation of heat.

5. In order to be of use to the body, food must be prepared, broken up by the teeth, and made soluble by the action of chemical agents secreted by various glands, and so fitted for absorption. The suitable portions are then, by a peculiar selective power, absorbed into the blood ; the rest being excreted—in technical language, must be formed into a state called chyme: the useful portion, the chyle, being absorbed ; the useless portion, the fæces, excreted. Most of the nutriment absorbed is consumed in the support of life, in keeping up the heat of the body, supplying the secretory organs, and repairing the tissues ; the rest is excreted by the lungs, kidneys, &c., as also the matter which becomes useless ; for all matters subserve vital processes but for a more or less limited time ; then, becoming useless (and even injurious, if retained), are discharged. If food be not taken, the body will lose about 40 per cent. of its weight, when

death will take place from starvation; the blood losing about 75 per cent. of its weight, fat 95, muscle 36, bone 15, nerve 5, viscera 25—70.

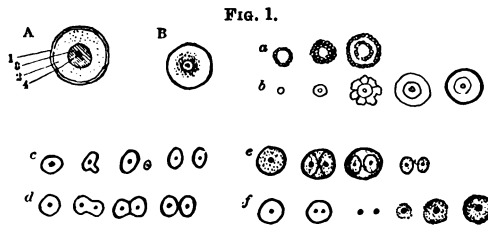
6. The chief sources of *gain* to the body are the alimentary canal, lungs, and skin; of *loss*, the lungs, kidneys, skin, the tissues generally—the secretory and excretory organs especially. The body *excretes* per diem about 106 oz.: by the skin, 34; lungs, 17; intestines, 5; kidneys, 50. These substances are—carbon, 8 oz.; water, 95 oz.; salts, 2 oz.; urea, 1 oz.; other organic substances, 20 grains. Animals are thus great decomposers of organic substances, converting nitrogenous and carbonaceous food into urea ($\text{C H}^4 \text{N}^2 \text{O}$), carbonic acid (C O^2), and water ($\text{H}^2 \text{O}$). The body *secretes* daily about $30\frac{1}{2}$ lbs., containing 10.372 grs. of solids—of which 2.297 are special solvents: nearly the whole of the secretions are, however, re-absorbed.

7. The body may be roughly considered as consisting of (1) organs of organic or 'vegetable' life, i. e. of nutrition; and (2) organs of animal life—of correlation (motion and sensation); (3) the organs of reproduction being relatively of inconsiderable anatomical importance.

The organs of Nutrition are of three kinds: (1) those of digestion and absorption, which prepare and absorb nutriment; (2) of circulation, which carry it to all the parts of the body; (3) those which keep it pure. The nutritive organs are termed viscera, and are contained in a great sac as it were. This sac is divisible into an upper somewhat conical part—the *thorax*—protected by a bony cage formed by the ribs, and containing the two chief organs—the heart and lungs—which are separated from the lower part—the *abdomen*—by a partition called the diaphragm—the more important of the abdominal viscera being pretty well protected by the thorax, since they lie in the concavity of the diaphragm.

The organs of Correlation are the bones, which serve as bases of attachment; the muscles, which move these, and thereby parts or the whole of the body; and the nerves, which supply to the muscles the motor impulse, and receive sensations of external and internal influences.

8. The various parts of the body, when viewed under the microscope, consist of different kinds of tissue. At first the rudiment of the body consists of an apparently structureless formative protoplasmatic fluid blastema, in the matrix of which float particles, usually more solid, and of a different optical aspect; these are, or coalesce to form, nuclei, around which are formed cells; but the cells and intercellular substances become differentiated—variously modified—chemically and histologically, and thus are developed into the different tissues. The simplest differentiated form of organic matter is the cell. A typical cell consists of an external envelope or *cell-wall*, containing the *cell-contents*, in the centre of which is the *nucleus*, containing a still smaller *nucleolus*. There may be several nuclei to one cell, and several nucleoli to a nucleus, and the cell-wall is sometimes absent. The cell-wall consists of 'periplast,' and the cell-contents of "endo-



A a typical cell: 1 cell-wall; 2 cell-contents; 3 nucleus; 4 nucleolus.

B a cell showing the germinal matter in its central part.

a and b development of cells *de novo*.

c gemmiparous, d fissiparous, e endogenous, f exogenous methods of reproduction.

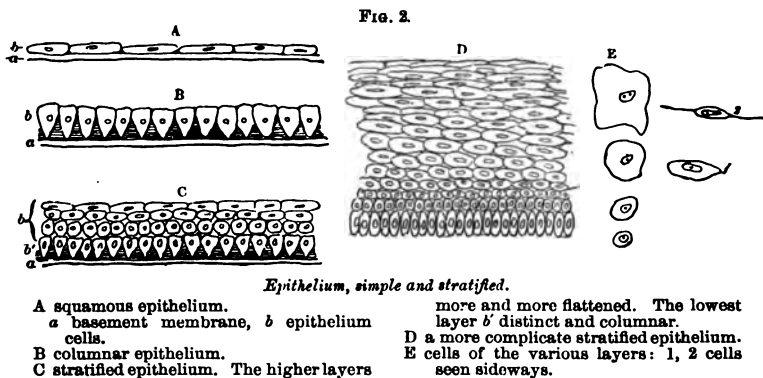
In a, c, d, e, f the nucleoli are ignored.

plast,' which is made up of protoplasm, in which float fat particles and granules. The nucleoli, according to some (but denied by others), are invariably of fat, and albumen coagulating round these, forms the nucleus: others think that the nucleoli are developed within the nuclei, after after the formation of the latter. When cells originate *de novo*, which is doubted, around the nucleus is formed a delicate membrane—the cell-wall; between these—fluid—the cell-contents—gradually intervenes: some think that small masses, the cell-contents, gather around the nuclei, the cell-wall being afterwards developed. Some look upon a typical cell as consisting of an active agent, the nucleus,

and a certain amount of living cell contents around it, and by these two parts, collectively termed the 'germinal matter,' all the differentiated structures are produced. According to these, fibres are produced by the nuclei travelling along, gathering fresh germinal matter, and leaving in their wake the posterior portions of the germinal matter developed into fibrous matter; thus as the nucleus travels the fibre is lengthened. So all fully-organized parts—the outer cell contents, cell-walls, and intercellular substance, with their modifications, are regarded as being no longer under the influence of vital force; but this is probably untrue. Cells are formed from pre-existing cells in four ways: (1) Gemmiparously, by a small bud from the cell becoming detached and developed. (2) Fissiparously, by the elongation of the parent cell, which contracts in the middle, the nucleus subdividing, and the two (or more) new nuclei drawing the contents each way till either the young cells gradually separate, or a partition is formed between the nuclei, and this, splitting into two, the young cells are completed. (3) Endogenously, the nucleus segmenting, and a new wall forming around each new nucleus; when developed, the wall of the parent cell bursting and setting them free. (4) Exogenously, the nuclei being freed from the parent cell before developing new cells. Cells may die a natural death, as it were, by dissolving or bursting; may become hardened or become charged with matter, and perhaps be permanently deposited; or they may undergo transformations—send out processes which may form networks with those of other cells; may run into each other—the ends of the cells being absorbed, thus forming tubular sheaths; or become flattened and joined together at the edges, forming membranes. The nuclei may become external (?) or embedded in the cell-wall; may survive the cell or disappear first; or may, perhaps, be converted into fibre.

9. The cells which line the inner free surfaces of all the membranes of the interior of the body are called epithelial cells. Sometimes the epithelium consists of only one layer of cells, sometimes of several (is stratified). The epithelium is generally covered externally by basement membrane, and

outside this, again, by areolar tissue. The epithelium of the digestive canal corresponds to the epidermis of the skin ;

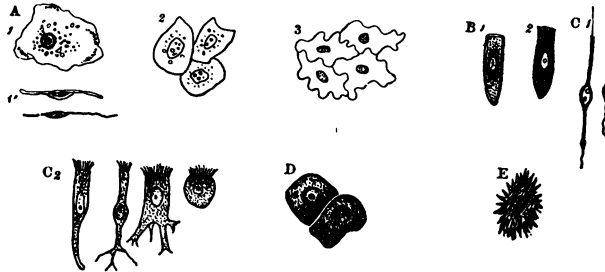


and to both conjoined is applied the term 'ecderon:' the cutis and corresponding areolar tissue of the digestive canal being classed together as 'enderon.'

10. Epithelial cells have usually a nucleus with one or more nucleoli. There are five kinds: (1) Squamous, forming the tessellated epithelium of serous membranes. (2) Columnar, lining ducts, &c. These sometimes have the free wall thickened, forming a seam, porous, and perhaps consisting of cohering parallel vertical rods: this kind is intermediate between the true columnar, and (3) Ciliated; ciliated cells have usually from 6—12 ciliæ, which are little flexible hair-like rather tapering filaments $\frac{1}{30000}$ in. long, which contract in a vibratory manner, about 700 times per minute; the ciliary current travelling $\frac{1}{3000}$ in. per sec. (in frog). These cells are generally columnar in shape, but sometimes spheroidal, contain a nucleus and nucleolus, and are sometimes found to send down prolongations to join the connective-tissue cells. The ciliæ occupy the free wall only. Ciliated epithelium may be stratified, the lower layers becoming more spherical, and being always devoid of ciliæ. Whether they are derived from the epithelial or connective tissue cells is uncertain—probably the former. These cells are found (A) in the respiratory passages—the major portion of the nostrils, upper pharynx, most of larynx, trachea and bronchiæ, also the Eustachian tubes, and part of tympanic cavities,

the nasal sacs and lachrymal ducts; (B) in the central canal of spinal cord, in parts of the walls of the brain ventricles, and in the pituitary body. (C) The excretory ducts of various small racemose glands, e. g. of tongue, &c. (D.) In the reproductive passages: in the male, from the vasa efferentia to upper part of epididymis; in the female, from middle of cervix, the uterus and its glands and the Fallopian tubes to their fimbriated extremities. Belonging to this class, and intermediate between it and the seamed columnar, should, I think, be reckoned certain cells supplied with one or more hair-like filaments, which are incapable of movement, and sometimes are quite stiff and brittle. (4) Glandular

FIG. 3.



A squamous cells: 1 from the mouth; 1' seen sideways; 2 from a serous membrane; 3 from a lymphatic duct. B columnar cells: 1 ordinary; 2 seamed. C 1 hair-bearing cells; 2 the ciliated cells. D glandular cells. E a furrowed cell.

cells of spheroidal or polyhedral shape, found in the secreting portion of glands. (5) Furrowed cells with dentated edges, and sometimes developing spinous processes, found in the lower layers of the ecderson, may be considered a variety of squamous. Cells are of various colours. Usually the nucleus is clear. Sometimes the cell-contents are so loaded with coloured matter that the production of pigment seems to be the object of the cell. These pigment cells are of various shapes, and are found in various parts. The pigment granules may be diffused through the cell contents, or grouped (usually around the nuclei); the particles are nearly colourless, except when viewed in a mass. Nearly all young epithelial cells are more or less spheroidal. When the epithelium is stratified, the *lowest* layer is usually columnar, and seems to reproduce itself; immediately above this are several

layers of cells; the lowest, which are the youngest, being small and spheroidal, those at the surface larger and more flattened, the cells being pushed up towards the surface by the growth of new cells below, and the old cells being thrown off. Sometimes some of the epithelial cells send down processes which are probably connected with the cells of the subjacent connective-tissue, e. g. in the urinary apparatus, trachea, &c.

11. Basement membrane (or *membrana propria*) is a very thin transparent structureless membrane, which forms the middle layer of serous and mucous membranes, of the skin at parts, and is found in the coats of many vessels, &c. Some basement membranes are found to consist of delicate nearly structureless squamous cells.

12. Mucous membranes are composed of (1) an inner layer (or layers) of epithelium of various shapes, (2) basement membrane, (3) areolar tissue. Their free surface is always in indirect communication with the air, e. g. inner wall of intestines. They are moistened by mucus, secreted by little follicular glands, sometimes by small racemose glands.

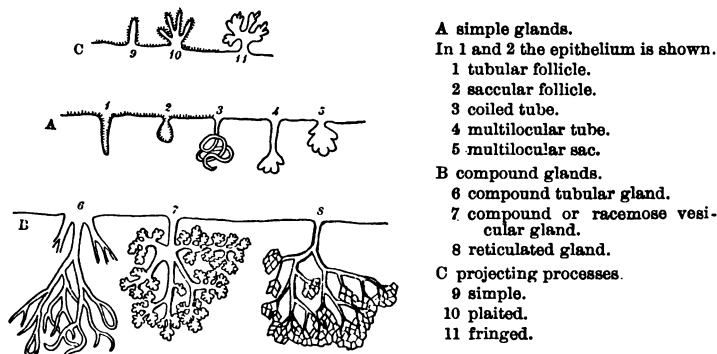
13. Serous membranes always form closed sacs, as the pleuræ, pericardium, and peritoneum.* They consist of (1) a single layer of squamous epithelium, the cells of which are nucleolated, (2) basement membrane, (3) areolar tissue. Their inner (or free) surfaces glide against each other, and are therefore moistened by the serous fluid, which is identical with lymph plasma. Serous membranes are *not* supplied with any proper glands.

14. The productions of the body are said to be *secretions* when the substances produced are made use of again: *excretions* are the useless (or injurious) substances thrown off. The secretions (and some of the excretions) are produced by glands which draw out from the blood and elaborate certain substances required. Some glands are continuously active, others intermittently so, their activity depending upon nerve-stimulus; usually from peripheral irritation in the intermittent glands, as from the presence of food. Glands may be looked upon developmentally as indentations of the membrane in which they are found, the indentations being

* The peritoneum of the female is an exception.

of various depths and forms. The tubes, or follicles produced, are formed of basement membrane, lined on the free surface by epithelial cells, and held together externally by areolar tissue, or embedded in it, or some other tissue. The basement membrane may also be absent: the essential portion of glands being the *glandular cells*. The epithelial

FIG. 4.



cells of glands are always glandular in the active or secreting portion, generally columnar in the ducts which carry away the fluid. The glandular cells are the agents of selection and secretion. Glands are always well supplied with blood by capillary plexuses.

Glands are both simple and compound. *Simple*: Tubular follicles, saccular follicles, coiled tubes, multilocular tubes, multilocular sacs. *Compound*: all consisting of branched tubes, which generally divide and subdivide into very minute tubules: compound tubular glands with the tubes ending freely in loops; compound (or racemose) vesicular glands, the tubes ending in a cluster of vesicles or saccules; reticulated glands, the tubes ending in a network.

15. The body, as before mentioned, is composed of various tissues, which are constantly changing more or less rapidly, old matter decaying and becoming re-absorbed into the circulation, and new being deposited, only two of the structures being deciduous—teeth and hair—(although effete cells get thrown off individually from the epidermis and the various epithelia). The fundamental tissues of the body have been *popularly* classified as follows:—

1. Simple membrane. Structureless, and employed solely in the formation of compound membranes, being then possibly secreted by adjoining cells, e. g. *membrana propria*, walls of cells, &c.

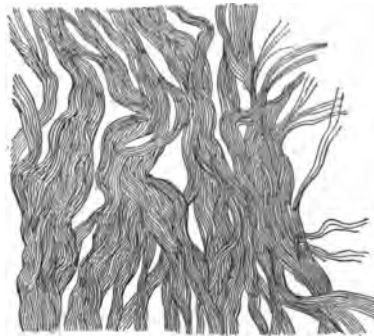
2. Fibrous tissue. White and yellow fibrous and areolar tissues, muscle, nerve tubules, &c.

3. Cellular tissue, cartilage, fat, bone, nerve-vesicles, &c.

The various tissues are more or less complicate and compounded, some being intermediate, i. e. fibro-cellular. Their exact structure and development is at present but ill understood, owing to different modes of preparation, &c.; so that we have very many different and confusing accounts. The size of the fibres and cells usually *varies excessively*—sometimes as much as 1 : 10 ; those given are rough approximate averages.

16. *White fibrous tissue* consists of wavy, flexible, tough, inextensible, inelastic fibres : $\frac{1}{16000}$ in diam.

FIG. 5.

*White fibre.* Highly magnified.

17. *Yellow fibrous (or elastic) tissue* consists of cylindrical

FIG. 6.

*Yellow fibre.* Highly magnified.

FIG. 7.

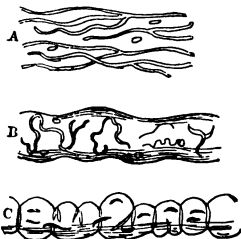


Various forms of elastic fibres.

flexible, highly *elastic* fibres : when broken, the ends of the fibres curl up, giving them a characteristic appearance : this tissue is generally found as a network of fibres—rarely as a homogeneous membrane : size of fibres $\frac{1}{4000}$ — $\frac{1}{24000}$ in. diam.

18. *Connective* or *areolar tissue* consists of a network of white and yellow fibres, containing numerous small areolæ, or spaces, which intercommunicate and are filled with a serous or lymph-like fluid and cells. White and yellow fibrous tissues are never to be found quite pure, being usually more or less intermingled as connective tissue, or else mixed with cartilage. Connective tissue is slightly elastic, and contains but few blood-vessels and nerves. It is very abundant

FIG. 8.



Areolar tissue, magnified (treated with acetic acid).

The white fibres are no longer seen, the nuclei and yellow fibres alone remain visible. A, B, C various appearances. C displays the constricting bands described.

FIG. 9.



Ramified connective-tissue corpuscles (from synovial membrane).

throughout the body. When condensed it forms sheaths as -lemmas, &c. It is sometimes badly called cellular tissue. The white fibres are found as parallel bundles of fibrillæ, and as a network of interlacing fibrils. In water the bundles swell up, lose their fibrillated aspect, and appear as an annulated cylinder, or a spiral : this is probably due to fibres surrounding the bundle, and which are probably derived from a sheath, torn by the swelling up of the bundle, and splitting into rings, or a spiral. Amongst, and sometimes within the fasciculi, are found cells of various shapes : these cells are possibly white blood corpuscles transuded through the capillary walls ; they are either (1) amœboid (or leucocytes) which are the most common, and are sometimes of a spindle shape, sometimes flattened : they sometimes exactly resemble the white corpuscles with one or more nuclei and

nucleoli, but more commonly are larger granular cells; the amœboid movements are sluggish; (2) branched cells. The corpuscles have no cell walls, and some think they are nuclear (have no true cell contents). There are three theories of development—(1) that the white fibre is developed from the fusiform, or spindle-shaped cells, becoming elongated and splitting into parallel bundles; and the branched cells into meshworks, which sometimes form a felted mass, called retiform or reticular tissue,—the yellow fibres arising from the intercellular substance; (2) the white from coalesced fusiform cells, the yellow from stellate cells; (3) both kinds from the intercellular substance. Some think that the cell-nuclei give rise to the fibres around the bundles, or else to the yellow fibres; others that the latter are produced by the substance immediately surrounding the nuclei; others that the white is produced by travelling germinal matter. The interfibrillar substance is at first granular, then homogeneous. The intercellular substance is probably secreted by the cells. Yellow fibres, however, are sometimes produced after the cells have disappeared. Connective tissue is variously modified, appearing sometimes as (1) fibrous tissue, a dense form, devoid of areolæ, and generally very tough, with but very little yellow fibre, and having the corpuscles elongated except in tendons. It forms *ligaments*, sheets used for binding bones together; *fasciæ*, felted sheets; *aponeuroses*, fasciculated sheets—the fasciculi parallel, or as but few decussating sets: *tendons*, cords used, like aponeuroses, for the attachment of muscles; the

FIG. 10.



Three chains of tendon cells between tendon bundles.

FIG. 11.



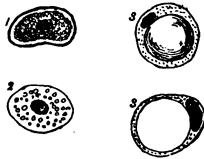
Transverse section of tendon showing branched cells enclosing tendon fasciculi.

fibres of tendons are parallel, and the corpuscles are arranged in rows in the angles between the tendinous bundles, and send out flattened laminæ, which partly surround the bundles; the nuclei are at alternate ends of the cells, so

that two appear together; tendons are so tough that it requires a force of 1000 lbs. to rupture the tendon Achilles (at the back of the ankle). (2) Jelly-like, containing the connective-tissue cells; very rare except in the embryo. (3) Homogeneous tissue devoid of corpuscles. When connective tissue runs into cartilage, the change is gradual—the cells of the latter becoming gradually branched and modified.

19. Adipose tissue, or fat, is a modified form of connective, consisting of clusters of nucleated fat-cells, $\frac{1}{450}$ — $\frac{1}{1000}$ in. diameter, and surrounded by capillary loops. These clusters are imbedded in the areolæ of areolar tissue. The cells are

FIG. 12.

*Fat cells and their development.*

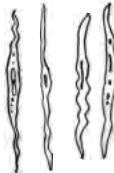
- 1 connective-tissue corpuscle loaded with minute fat globules.
- 2 the globules increase in size and coalesce.
- 3, 3 fully developed cells, in which the minute globules have coalesced into one.

originally connective tissue corpuscles, in which oil accumulates; at first, in globules. Adipose tissue serves as padding, giving protection, support, warmth, and roundness to the figure. Sp. g. .932.

20. Muscular tissue is of two kinds: (1) non-striated, organic, or involuntary, (2) striated, or voluntary.

21. Non-striated or smooth muscular fibre consists of bands of rod-like spindle-shaped cells, with oblong nuclei and nucleoli, and no cell-wall; sometimes several smaller nuclei are seen: the cells are sometimes rather irregular in

FIG. 13.



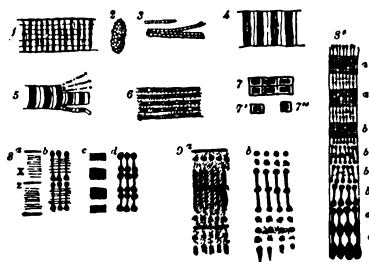
Four non-striated muscular fibre-cells; one with several nuclei.

shape. Length of cell $\frac{1}{300}$ — $\frac{1}{800}$ in.; diam. $\frac{1}{2800}$ — $\frac{1}{7000}$ in. It is found in the coats of almost all the vessels; and also

attached to the roots of hairs, and the epidermis above them, giving rise, when contracted, to the 'hair standing erect' (horripilation), and to 'goose-skin' (cutis anserina).

22. Striated muscular fibre (the lean flesh of meat) consists of parallel fasciculi, or bundles of fibres invested in a sheath of, and bound together by areolar tissue. Each fibre consists of an apparently structureless sheath of modified connective tissue, much resembling yellow fibre, but which, upon more minute examination, seems to consist of flattened cells; this sheath, the sarcolemma or myolemma, encloses the contractile substance of the fibre, which may split longitudinally into fibrillæ, or transversely into discs. Appearances differ with the magnifying power. Each fibre appears to consist of alternate dark and light transverse stripes, the latter being narrower, and each having a layer of dark par-

FIG. 14.

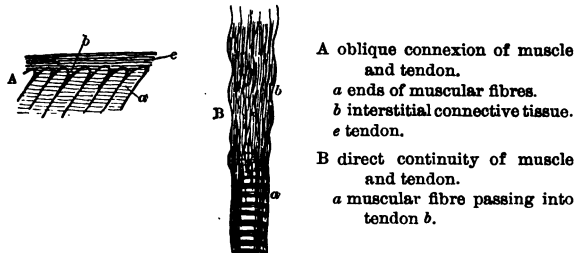


1 portion of a striated fibre showing the dark and white stripe and longitudinal lines; it may split into discs like 2 or fibrillæ 3. 4 a fibre more highly magnified, showing the dark stripe through the light disc. 5, 6, 7, three theories of composition. 7' beads viewed sideways, 7'' endways. 8 another theory. a appearance of a fibre. x dark stripe. z light stripe with narrow dark one through its centre. b showing how caused by rods, &c. c a contracted fibre. d explanation. e appearance according to this theory of a fibre at a contracted. f various stages of contraction. g complete contraction; it will be seen that the dark portion of uncontracted fibre corresponds to the light portion of contracted fibre, &c. h a appearance according to another theory. i its explanation.

ticles in its centre. Each fibrilla or fibril viewed sideways seems to consist of a row of darkish oblong rectangular beads, between each bead being interposed some lighter coloured substances, as also—though of slightly different nature, between the fibrils: viewed from above, the beads are 3, 4, or 5-sided. Under certain circumstances, both the beads and intervening substance appear to be striated. Some think that the fibrillæ have no real existence, the fibre being capable of being so split up ad infinitum. Others

again think that in each fibre (1) there are phalanxes of minute longitudinal rods with enlarged ends—the substance between the central parts of the rods being different from the rest, (2) phalanxes of minute columnar rods with a granular disc, or kind of septum between each phalanx, the rods themselves presenting enlargements at both ends, and at the centre. Fibres neither divide nor anastomose: the tongue offers an exception to this rule, the fibres dividing and subdividing. When muscles join tendons (1), if the direction is the same, the muscular fibre is directly continuous with the tendon fibre (2), if joined at an angle the rounded ends

FIG. 15.



of the muscular fibres push into depressions in the tendon, the connective-tissue sheaths surrounding both being continuous with each other. Muscle is composed of myosin, which, after death, becomes syntonin. Sp. g. of muscle 1.020. Size of fibres $\frac{1}{400}$ — $\frac{1}{800}$ in. diam., fibrillæ $\frac{1}{10000}$ — $\frac{1}{18000}$ in. diam. In development either the fibrillæ are formed by travelling germinal matter, or each fibre is probably composed of a number of primary cells, which coalesce to form a tube which grows in length, the septa being absorbed, and the nuclei, surrounded by some cell-matter lying within and against the walls of the tubes (in the embryo embedded among the fibres). The cells very probably are devoid of walls, the fibre-sheath having a separate origin.

23. Nervous tissue also comprises two varieties, white and grey matter. White nervous matter consists of fibres only—grey of fibres and cells. Nervous tissue consists of two components—cells and fibres.

24. Nerve corpuscles, cells, or vesicles, are the most im-

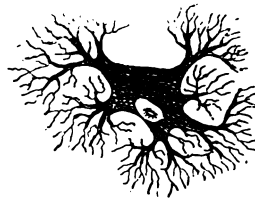
portant constituent of grey nervous matter or ganglionic nerve-substance, being always mixed with cell-processes and delicate intervening fibres. Each cell consists of a finely granular substance, with a nucleus and nucleolus. There may be two nuclei, and four or five nucleoli: there are multi-nucleated cells in young animals. In the cerebro-spinal

FIG. 16.



a nerve cell-corpuscles.
 b nucleiform bodies found free in the cerebellum.
 c a ganglionic nerve-cell: 1 free; 2 appearance in its capsule; 3 (imaginary) section of capsule.
 d a nerve-corpuscle, and e a nerve-decussation, both showing the course of the fibrillæ.

FIG. 17.



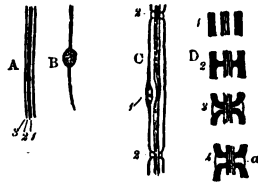
A stellate nerve-corpuscle.

region, the cell-wall is very delicate or absent. Nerve-cells are of various shapes, being round, oval, pyriform, tetrahedral, or irregular. They almost always send out one or more processes or poles, all fully-developed cells are probably branched. Cells are (1) apolar (and enveloped); probably undeveloped cells, as also the (2) unipolar, which are common in the spinal ganglia; (3) bipolar, in posterior nerve-roots, and some sympathetic ganglia; (4) tripolar, in posterior cornua; (5) tetrapolar, and (6) multipolar (up to ten or twelve branches), in anterior cornua and brain. The protoplasmatic prolongations or poles often subdivide, and probably always run into those of other cells, or are continuous with the axis-cylinders of nerve-fibres. Size of cells: $\frac{1}{100}$ — $\frac{1}{50}$ ($\frac{1}{100}$ — $\frac{1}{50}$) of nuclei $\frac{1}{100}$. Sp. g. of grey tissue 1.009 upwards. It consists of 86 per cent. of water, $3\frac{1}{2}$ —6 phosphuretted fat, &c.

25. Nerve-fibres, tubes, or tubules constitute the white nervous matter, Sp. g. up to 1.030. Water 66 per cent. upwards, phosphuretted fat 16—18 per cent. A nerve consists of a fibrous sheath, neurilemma, enclosing numerous small fibres connected by areolar tissue. A typical white (or 'dark-bordered') nerve-fibre consists of (1) an external

homogeneous sheath, the limiting membrane or primitive sheath, (2) an intermediate white fatty substance (containing phosphorus), the medulla, medullary sheath, or white substance of Schwann, (3) a central albuminous band, the axis cylinder or band of Remak: 3 is essential, 1 may be absent as in white portion of cord, 2 is absent in various places,

FIG. 18.



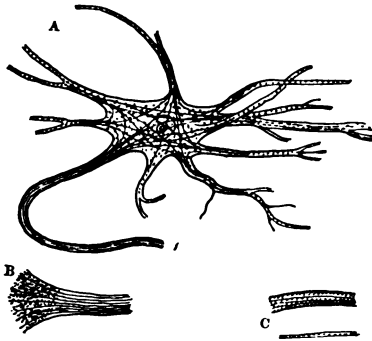
- A a white or dark-bordered nerve-fibre.
 1 axis-cylinder.
 2 medulla.
 3 primitive sheath.
 B pale fibre.
 1 a nucleus.
 C a nerve-segment.

- 1 a nucleus embedded in the primitive sheath.
 2, 2 nodes of Ranvier.
 D probable development of the nodes of Ranvier. The axis-cylinder is continuous.
 a intersegmental substance.

1 and 2 may be absent, as in peripheral terminations, and at junction with cells in grey portion of cord; they are then called pale or *yellow* nerve-fibres. Here and there upon the white fibres are seen certain bands, the nodes of Ranvier; at these points the continuity of 2 is broken, 1 dipping in between, and generally more or less intersegmental substance splits 1 into two. To each segment, about midway between the nodes, is a nucleus, surrounded by a little protoplasm, and lying against and within the limiting membrane. White fibres break up peripherally and centrally into pale fibres. White fibres sometimes present a varicose appearance, probably artificial. The exact connexion of fibres and cells is but indefinitely known; probably there is no fibre unconnected with a cell. In the anterior cornua, axis cylinders go directly to a cell, are more distinct, and do not join in a branch; in other parts they do. Sometimes two spiral pale fibres coming from a cell unite to form a white fibre. Granular nuclear masses are frequently to be found along the pale fibres. In the sympathetic ganglia the ganglionic corpuscles are surrounded by a distinct nucleated capsule, in continuation with which perhaps, but not probably, are the *grey* gelatinous nerve-fibres of Remak: this envelope has

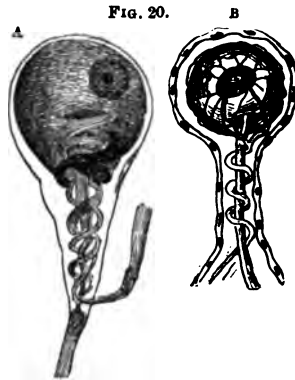
sometimes an epithelium-like lining. These grey fibres are nucleated, and by some are considered *identical with the yellow fibres*; by others, their nervous nature even is doubted. Either (1) the white fibre is connected with more central portion of cell-contents, pale fibres with peripheral portion, in which are imbedded the nuclei seen, and not in the sheath, which is continuous with that of the white fibre; or (2) the axis-cylinder runs directly into the nucleolus; the medulla being connected with the nucleus; the pale fibres break up, and form a network in the cell before joining the nucleolus, the cell-envelope being distinct and nucleated. In large caudate (or branched) cells, intersecting lines (rows of minute

FIG. 19.



a multipolar nerve-cell. 1 axis-cylinder process.
 b origin of an axis-cylinder process which becomes non-granular.
 c sections of two other processes (not axis-cylinders).

FIG. 20.

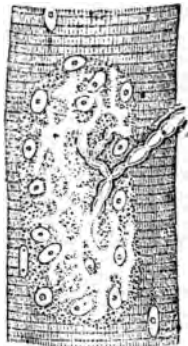


Nerve-capsule.
 A according to Beale.
 B according to Arnold.

granules) are seen, some very distinctly, one or more joining together every prolongation, a great number of very minute ones also. The axis-cylinder is also sometimes striated (as in nerves of special sense); but there are no granules between the striæ of the axis-cylinder, thus both cells and fibres are probably fibrillated. The fibrillated structure is rendered extremely probable by the fact that each white fibre breaks up peripherally into several pale fibres, and that cell-prolongations generally do the same. The primitive fibrils pass through the cell from one prolongation to another. The size of the white fibres is $\frac{1}{2000}$ ($\frac{1}{1500}$ — $\frac{1}{1200}$ or $\frac{1}{2000}$), of fibrillæ down to $\frac{1}{100000}$, yellow or grey fibres $\frac{1}{5000}$ — $\frac{1}{10000}$ in. diam.

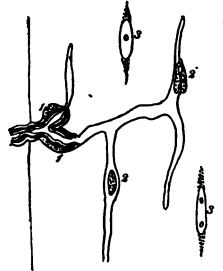
26. The peripheral termination of nerve-fibres is unknown: to account for this difficulty it was once proposed that they ended in loops; now it would seem that the white fibres broke up into branches of yellow fibres, which unite together and form a network of pale fibres (with frequent nuclei upon them), thus really ending in loops as it were. In glands,

FIG. 21.



End-plate of Kuhne, with nerve-termination (from a lizard). Three muscle nuclei are also seen.

FIG. 22.



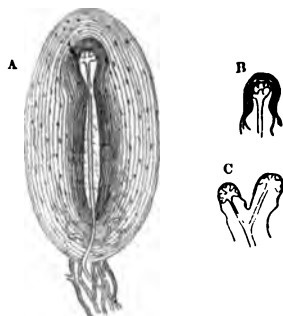
Termination of a branch of a terminal nerve fibre (in frog).

1, 1 nuclei of primitive sheath. 2, 2 nerve-nuclei. 2' shows the minute fibril given off from the underlying fibril and terminating in a bulbous enlargement. 3, 3 muscle nuclei.

the minute fibrils terminate in the nuclei, sometimes nucleoli of the glandular cells: in non-striated fibres, also in the nuclei, sometimes nucleoli. In striated muscular fibre, in a granular effused plate, containing nuclei, (not muscular germinal matter). The limiting membrane is continuous with the sarcolemma, the medulla with the granular matter, the axis cylinder either being also continuous with the granular matter, or more probably ending in subdividing branches among it; the branches send up minute processes into the granular nuclei upon them, one process to a cell. Some think that the nerve never enters the sarcolemma; the small branches overlying it. At this point the fibres have been seen to change direction, turning backwards so as to form a loop; but this must be rare, for others say that there is one such terminal or 'end-plate' of Kuhne to each fibre near the middle. There is one nerve-fibre usually to 6 or 7 muscular fibres (1—80). Nerves are sometimes seen to terminate in a granular bulbous enlargement of the axis cylinder. Rarely nerves end in certain stellate or ganglionic cells found in the

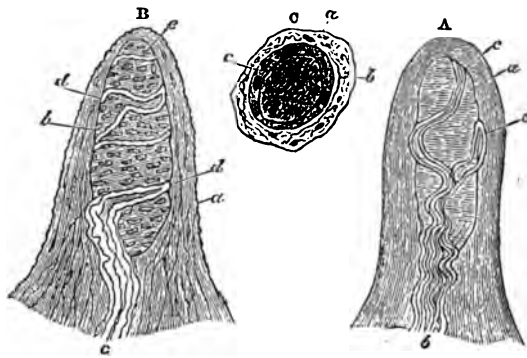
epidermis and elsewhere. In the nerves of special sense, the ultimate fibrils terminate in special cells, generally forming a network first. The nerves of ordinary sensation many of them terminate in certain peculiar bulb-shaped structures, of which there are three kinds. (I.) Corpuscles of Pacini (or of Vater) size $\frac{1}{8}$ — $\frac{1}{10}$ in., found generally throughout the

FIG. 23.



A Pacinian corpuscle magnified. The capsule lamellated, one nerve enters the core, several capillaries pass inwards among the lamellæ.
B Termination of the nerve more enlarged. C bifurcated ending.

FIG. 24.



Papillæ containing tactile corpuscles. (Kölliker.)

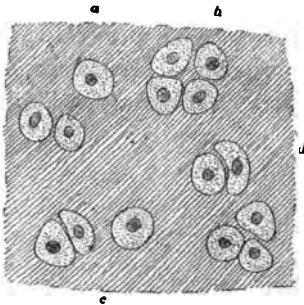
A papilla: *a* tactile corpuscle; *b*, *c*, *e* nerves. B papilla treated with acetic acid: *a* papilla; *b* corpuscle showing transverse nuclei; *c*, *d*, *e* nerves. C cross-section: *a* connective tissue of papilla; *b* nerve-fibril; *c* corpuscle sheath with nuclei; *d* core.

body, except in the cutis: each consisting of (1) an external capsule of connective tissue formed by about sixty concentric capsules with septa and fluid between, each capsule consisting of modified connective-tissue, lined by a nucleated squamous epithelium; (2) a granular nucleated bulb or core enclosing an axis-cylinder, often branched, the branches terminating

in enlarged extremities, the medulla being probably continuous with the granular matter, the sheath with the capsules. (II.) Tactile corpuscles found in the cutis of the skin, especially of palmar surfaces of hands and feet, where touch is acute, as many as 108 downwards to the sq. line: size $\frac{1}{300}$ by $\frac{1}{800}$: each consists of (1) a capsule with nuclei arranged circularly, and elastic fibre, (2) a granular bulb: 1 or 2 (to 3 or 4) nerve-fibres run spirally round the corpuscle two or three times, terminating by pale extremities at surface of central bulb. (III) Terminal bulbs of Krause $\frac{1}{600}$ ($\frac{1}{250}$ — $\frac{1}{1000}$), only found in a few situations—conjunctiva, tongue, glans-penis, and clitoris, resembling rather undeveloped tactile corpuscles—the central bulb granular or homogeneous, and entered by a straight fibre or two coiled ones,—the neurilemma being continuous with the capsule.

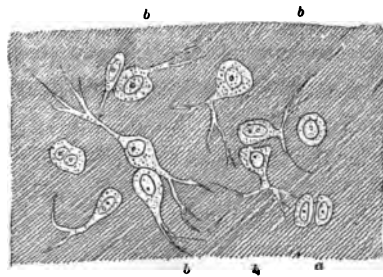
27. Cartilage (or 'gristle') is a very tough, firm, elastic

FIG. 25.

*Articular cartilage.*

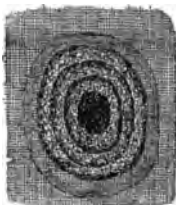
Showing groups of cells lying in the matrix.

FIG. 26.

*Transition of cartilage cells into connective-tissue corpuscles.*

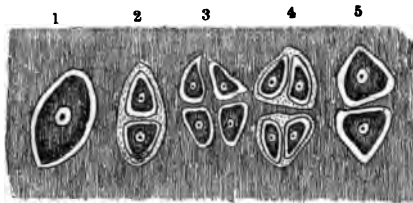
a cartilage. b, b transitional cells.

FIG. 27.

*Development of cartilage.*

Germinal matter being converted into matrix.

FIG. 28.

*Theoretical diagram of cartilage-cell multiplication.*

1, 2, 3, 4, 5 successive stages.

opalescent, substance, consisting of a homogeneous matrix—blastema—and numerous cells about $\frac{1}{1500}$ in. (containing

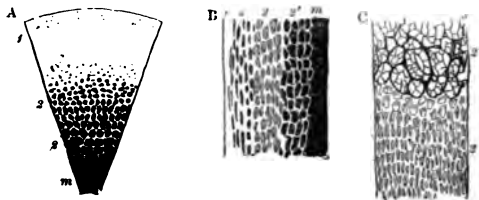
one or more nuclei and nucleoli), and sometimes free globules. The cells develop numerous thick capsules—the newest one being innermost—till finally about the whole of the intercellular substance is of capsular origin. The cells are often found in groups, which are vertical in the deep parts, but flattened parallel to the surface, near the periphery of the cartilage, which coats the surface of bones, which glide on each other—being then called articular cartilage. There are five kinds of cartilage—

(1) Temporary.—Fœtal, resembles (2) B, but cells are not grouped.

(2) Permanent {
 A. Cellular, also of fœtal origin.
 B. Hyaline, true or pure cartilage.
 C. Fibrous { white fibrous-c. or fibro-c., white fibre + c.
 mixed; elastic, yellow or reticular c.,
 yellow fibre + c.

28. Bone or osseous tissue is a tough, dry, hard, inelastic, yellowish-white substance: sp. g. of osteine or bone-substance, 1·900; of bone when fresh (including marrow) 1·200. Osteine consists chemically of about 31—33 per cent. of animal matter; the remainder inorganic. Phosphate of lime, 59·6 carbonate of lime, 7·3, &c. There are two kinds

FIG. 20.



Sections of osseous substance.

A transverse view. B vertical section. C front view.

e external surface. m medulla.

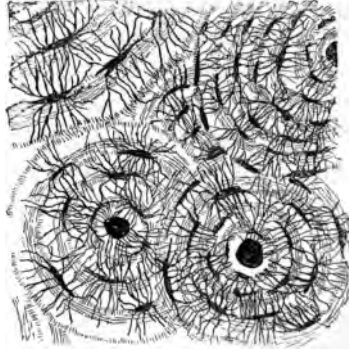
1 compact tissue. 2 lacunar form of cancellated tissue. 2' reticulated cancellated tissue.

In C the osseous reticulae are shown black.

of bony tissue; compact or solid, and cancellated or spongy. Compact bone—the typical kind, is traversed by a system of Haversian canals ($\frac{1}{300}$ diam. $\frac{1}{200}$ apart), around which the bone is arranged in concentric laminae, resembling the section of a dicotyledonous tree, each lamina consisting of an outer dark and inner clear portion. Between the laminae (and in the clear portions) are rows of spider-like bodies—

the bone-cells, osseous corpuscles, or lacunæ. The cells contain granular matter (nucleus probably, and some cell-contents, but no cell-wall), and each sends out numerous

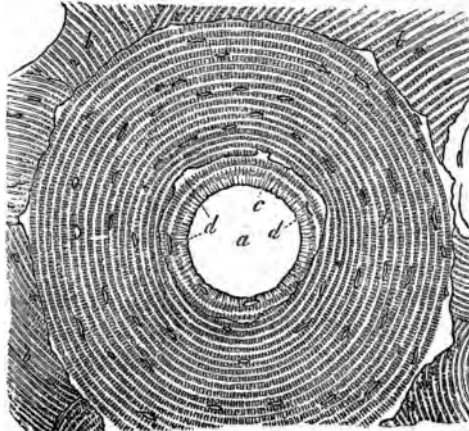
FIG. 30.

*Transverse section of dense bony tissue.*

The Haversian canals (in section) with their concentric laminae, lacunæ and canaliculi are seen.

canaliculi, many of which intercommunicate freely with those of neighbours, and also run into the Haversian canal, thus forming a nutritive system, corresponding to the lymphatic

FIG. 31.

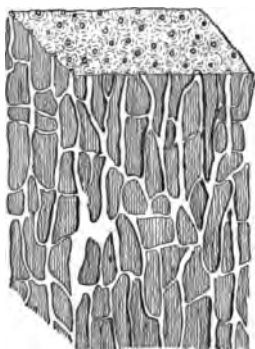
*Section of bone (highly magnified, Kölliker) showing the concentric laminae, &c.*

a Haversian canal. *b* lamina belonging to other canals. *c* transparent parts of laminae
d, d opaque parts.

canalicular system. At the peripheries of long bones, several rows of cells are found parallel to the surface: size

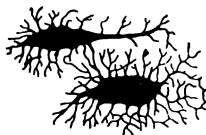
of cells $\frac{1}{3000}$ by $\frac{1}{3000}$ — $\frac{1}{5000}$, of canaliculi $\frac{1}{7600}$ or less. The bone substance, besides being laminated, is also reticulated—is composed of reticulating fibres, through which run a few transverse perforating fibres. Bones are surrounded by a layer of fibrous tissue—periosteum—in which the arteries subdivide before entering the Haversian canals; beneath this is a sub-periosteal blastema, containing fibres and granular nucleated cells. The long bones have cavities in their shafts filled with *marrow*, a highly vascular form of connective-tissue, loaded with fat (96 per cent.), and of a yellow colour. In all other places, and in young bones, the

FIG. 32.



Section of bone. Showing the Haversian systems cut longitudinally; the Haversian canals are left white. At the upper part of the figure the section is transverse, and the concentric laminæ are indicated.

FIG. 33.



Two bone corpuscles with their processes

FIG. 34.



A highly magnified section of bone.

b body of bone corpuscle. *c* canaliculi.
c' cross-section of canaliculi.

marrow is red and cellular ($\cdot 25$ solids, $\cdot 75$ water). The walls of the medullary spaces are also lined by a modified sub-periosteal tissue, containing (or being represented by) osteoblastic cells. Bone is developed from temporary cartilage in the following manner: the cartilage cells arrange themselves in rows (perpendicular to the axis in long bones); osseous matter becomes deposited as calcified granules, forming spiculæ between the rows; the granules increasing, surround and hide the cartilage-corpuscles: sometimes mineral deposit is formed within the capsules also: as the matrix becomes more calcified, it becomes transparent, and medullary spaces are formed in it by absorption; in these are

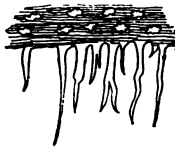
found 'osteo-blastic' cells, which multiply rapidly; these cells become surrounded by a fresh deposit of bone-matter, and themselves become the bone-corpuscles. This first deposit of bone is irregular, and the spaces formed by absorption may either accumulate and remain unfilled, thus forming cancellated tissue, or become filled with concentric rings of true bone-deposit, forming compact tissue. In both kinds continual re-absorption and deposit go on. In certain stages the bony deposit is sometimes 'globular,' consisting of united globular masses with interglobular spaces between. In *cancellated* tissue the osteine is in the form either of a network of spicules, or of laminæ, with more or less wide

FIG. 35.



A lamella of bone showing its reticular structure.

FIG. 36.



Perforating fibres.
a bone-cells. b perforating fibres drawn from their sockets.

FIG. 37.



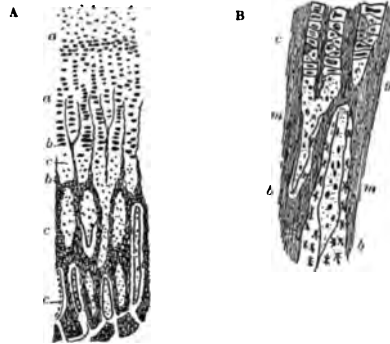
Theoretical section of the ossification of a column of cartilage cells.

- a ordinary cartilage cells.
- b cells becoming more globular.
- c the cells shrinking within the capsules.
- d two cells into which osteo-blasts have entered.
- e osteo-blasts which at f are becoming converted into bone-cells.
- g bone-cells.

interspaces, the former being the typical kind; in the interspaces is marrow, which far exceeds the osteine in quantity, in the typical kind. All stages between the scanty network and solid bone are to be found. Absorption is produced by means of large multi-nucleated cells, termed osteoclasts, probably developed from osteo-blasts, and which again perhaps split up into osteo-blasts. These cells are granular, and contain from two to ten clear nuclei with nucleoli, and often have the wall lying against the bone thickened, and sometimes striated. The osteo-blasts are found in the sub-periosteum, and also line the medullary spaces as an epithelium, penetrating the cartilage-capsules, as the cartilage is

absorbed, and the capsules rupture. The osteo-blastic cells are clear and granular, and apparently devoid of nuclei. Some think the bone-cells are derived from the cartilage-

FIG. 38.



A view of ossifying bone.

a cartilage cells at *a'* gathered into rows.

b granular spicules of osseous matter.

c medullary spaces at *c'* becoming lined with true bone.

B lower portion of above more highly magnified.

c cartilage cells.

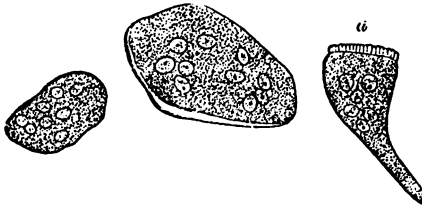
g granular osseous substance.

m medullary spaces containing osteoblasts, &c.

b true bone substance.

cells, the osteo-blasts being descendants of these latter. Cartilage sometimes (as rarely in old age) ossifies directly, but is then recognizable as such, the cells having no canaliculi, &c. Ossification is normally derived (1) from cartilage, as described; or (2) is intramembranous—from modified fibrous-tissue, corresponding to sub-periosteum, without the intervention of cartilage—as round the shafts of long bones after their first formation, and in the tabular bones of the

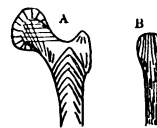
FIG. 39.



Three osteoclasts.

Two have thickened borders, one of these striated, *a*.

FIG. 40.



A upper part of the femur, showing the direction of the bone spiculæ.

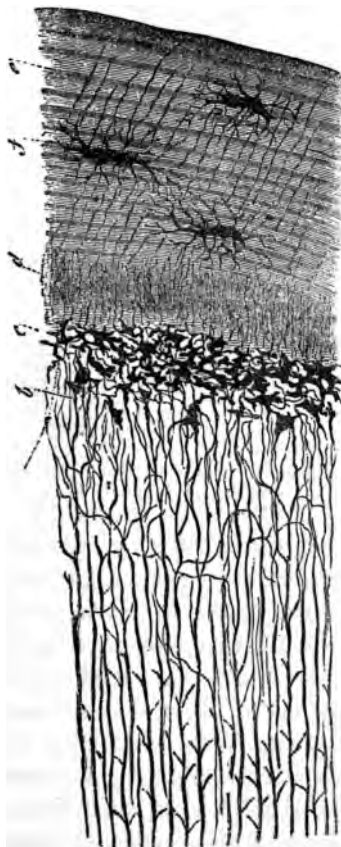
B upper part of the fibula.

skull. When bone arises from membrane, this membrane resembles modified connective tissue, the fibres becoming gradually ossified by the absorption of calcareous granules,

the cells becoming osteo-blasts ; the Haversian canals being formed by surrounded blood-vessels. The osseous spicular network radiates from the centre of flat bones. All bone developed from cartilage seems to be re-absorbed, so that cartilage should be looked upon as a basis of support for bone formation, and as a temporary skeleton. Bone, after its first formation, grows very slowly, and rather by accretion than by true growth, increasing chiefly by addition to the surface, but little by interstitial deposit.

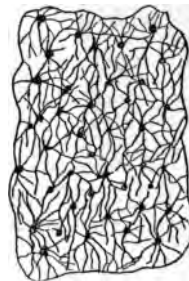
29. Teeth are composed of three kinds of tissue—(1) *cement*,

FIG. 41.



Section of dentine and cement. (Kölliker.)
a dentinal tubules passing at b into granular layer of Purkinje. c interglobular spaces. d, e, f cement.

FIG. 42.



Cross-section of dentine. (Kölliker.)
Showing canals (in section) and branches.

which forms the 'crusta petrosa,' is an irregular kind of bone, devoid of Haversian canals, and of any concentric dispo-

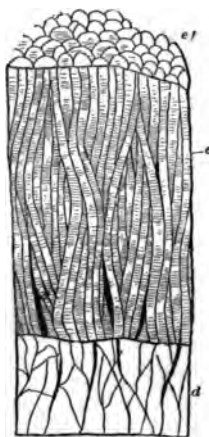
sition. (2) *Dentine* has an apparently fibrous structure owing to the existence of numerous tubuli ($\frac{1}{300}$ diam. $\frac{1}{300}$ apart) which run from the interior (pulp-cavity) to the exterior, each

FIG. 43.



Section of part of an incisor tooth. (Kölliker.)
a pulp-cavity. b dentine. c incremental lines.

FIG. 44.



Section of enamel.
d dentine. e enamel. e' enamel surface.

FIG. 45.

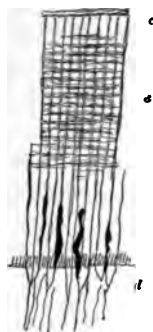


Section of enamel and dentine. (Kölliker.)
a enamel. b lacunae. c dentine.

dividing dichotomously a few times in passing outwards, giving off numerous branches on the way, and anastomosing with the canaliculi of the cement (where the latter exists). Each tube presents two or three slight curves, and numerous very fine spiral turns: there are also 'contour' or incremental lines seen crossing the dentine, due to interglobular spaces—the dentine there being imperfect and nodulated, or globular; elsewhere the interlobular substance is indistinctly laminated (concentrically). At the inner end of each dentinal tubule is a kind of cell, and each tubule contains an albuminoid fibre continuous with the cell-contents. Dentine contains about 72 per cent. of inorganic

matter. (3.) *Enamel* has a prismatic structure, consisting of six-sided fibres or prisms ($\frac{1}{3000}$ diam.), which run pretty vertically to the surface at the summit, more and more horizontally lower down, and are marked by transverse striæ. The fibres are not quite parallel, often interlacing slightly; they are arranged in alternating ranges, which cross each other at an angle near their bases, becoming more parallel at the surface of the tooth. The enamel prisms are also crossed by concentric brownish 'coloured' lines. Enamel only con-

FIG. 46.



Section of enamel.

e enamel. *c* cuticle. *d* dentine: its tubules passing into lacunæ and intercolumnar spaces in the inner part of the enamel.

FIG. 47.



Enamel prisms or columns seen longitudinally.

FIG. 48.



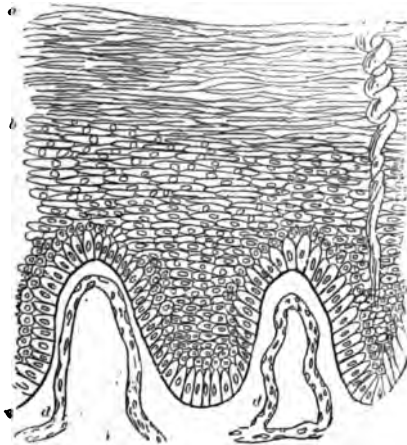
Hexagonal ends of enamel fibres.

tains $3\frac{1}{2}$ per cent., or less of animal matter, and is the hardest and most dense tissue of the body. The inorganic elements of the dentinal tissues somewhat resemble bone. A substance termed osteodentine is sometimes found in the pulp-cavity lining the dentine and gradually obliterating the cavity more or less by the formation of new layers. It much resembles bone, having Haversian canals and concentric lamellæ: from the canals radiate tubules, like the dentinal ones.

30. The *skin*, which covers the outer surface of the body, is of rather complex formation, consisting of two principal membranes. (1) The *Epidermis*, cuticle, or scarf-skin, outermost, formed by several layers or strata of squamous cells, the outer ones becoming more and more flattened, dry, hard, horny, and scale-like; the lower strata of newly-formed

cells compose the rete mucosum, mucous, or Malpighian layer; the newest cells, small and roundish, multiply fissiparously, and as they are pushed upwards towards the surface, become larger, flattened and horny. The innermost layer of cells are larger than the others, and are elongated vertically, being very pointed below. Many of the Malpighian cells contain coloured pigment (especially in the lowest layer, fading upwards), giving the characteristic colour to the skin; the carmine tints are due to the blood-vessels of the dermis. The lower mucous cells are ridged: the ridges

FIG. 49.



Section of epidermis.

a horny layers. *b* mucous layers. *c* columnar layer. *d*, *d'* capillaries in papillæ.

FIG. 50.



Development of epidermis.

a layer of Malpighian cells which become flattened into several layers of horny cells, *b*.

do not interlock, but meet, thus forming canals. In many places between the papillæ, and lying between the epidermis and dermis, is an excessively thin layer of basement membrane. (2) The *dermis*, *cutis*, *corium*, or true skin is composed of areolar tissue, well-supplied with blood-capillaries, nerves, lymphatics, and adipose substance. Its surface is rough, being thrown into papillæ, which in the palms of the hands and soles of the feet are arranged in rows; the papillary portion of tissue is ill-developed and highly vascular; the papillæ are sometimes simple, sometimes compound (branched), in some parts are rudimentary, and in others

again absent: length $\frac{1}{100} - \frac{1}{1500}$: on the palm there are 80 compound, or 200 simple to the sq. Paris line. A capillary loop is found in most of the (then termed 'vascular') papillæ;

FIG. 51.



Dermic papillæ.

a simple ones. b four compound ones.

FIG. 52.



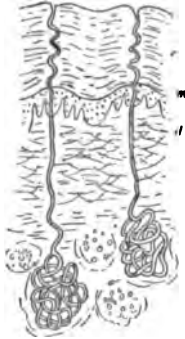
Magnified view of epidermic ridges caused by rows of papillæ beneath; furrows are seen across them; the mouths of the sudoriparous ducts are also seen.

in the others a nerve fibre or fibres run—rarely nerves and capillaries in the same.

31. In the skin are found certain glands, (1) Sudoriparous, perspiratory, or sweat-glands. Each consists of one (rarely two) coiled tube, which empties at the surface by means of a duct which in some parts is spiral. Each gland is supplied with its own capillaries, and consists of basement membrane lined by epithelial cells, which are continuous with those of the epidermis, and being incompressible, as these are pushed up among the flattened and *thinner* cells of the surface, the duct is obliged to assume a spiral shape. There are from 417 to 2736 per square inch, altogether about 2,381,248. Each about $\frac{1}{16}$ long, $\frac{1}{860}$ diam.: total length, if joined, 153,000 in., or about $2\frac{1}{2}$ miles: hence the importance of keeping the mouths of these tubes open by washing away all impurities from the skin. The skin itself is not *very* permeable, either to external substances, or to perspiration exuding through it, but these glands are *always* active, secreting perspiration, a slightly acid fluid .995 water, the rest salts with a trace of *oil* (independent of the sebaceous secretion). In general its evaporation is undistinguishable, and is called 'insensible perspiration,' of which about 34 oz. is given off daily: when noticed as sweat, the activity is 116 per cent. above the mean. The integument itself secretes an unknown (but small quantity) of perspiration. Moisture of the atmosphere checks perspiration, and as perspiration generates cold, hence the unbearableness of hot moist air, as compared with hot dry air. Checked perspiration in cold

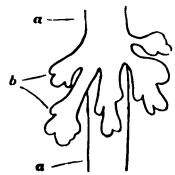
weather gives rise to rheumatism, &c. Perspiration is due generally to heat, but also to a temporary paralysis of the vaso-motor nerves, as by bodily exertion, fear, &c. Mental exertion increases it 42 per cent. (2.) *Sebaceous glands* consist of one or more saccular follicles, usually 5—20 sacculcles (or only one), the duct to which opens generally into

FIG. 53.



Two sudoriparous glands 29.
e epidermis. m Malpighian layers.
d dermis.

FIG. 54.

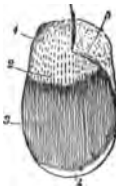


Sebaceous follicle with branched duct.
a, a hair follicle.
b, b two of the lobules of the sebaceous gland.

the neck of a hair-follicle—two (one or several) to each hair. They secrete an oily fluid, which serves for lubrication of the hairs and the skin—mixing with the perspiration. They are lined with an epithelium of cells containing fat, which become detached, and split into globules forming the fluid. Both sets of glands are derived from involutions of the rete mucosum, which become hollowed into tubes.

32. Two structures are found situated upon the epidermis

FIG. 55.



A nail.
1 root. 2 lunula. 3 body.
4 free edge. 5 epidermic fold.

FIG. 56.

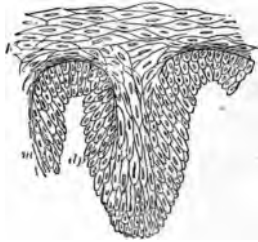


A longitudinal, and B transverse section of nail.
d dermis. m Malpighian layers. e epidermis. n nail.
b bed of nail. p papillae.

—nails and hair. There are twenty nails, one upon each

digit, close to the end. A nail is composed of modified epidermic cells, the cells of the mucous layers as they push

FIG. 57.



Transverse section of part of nail more highly magnified.

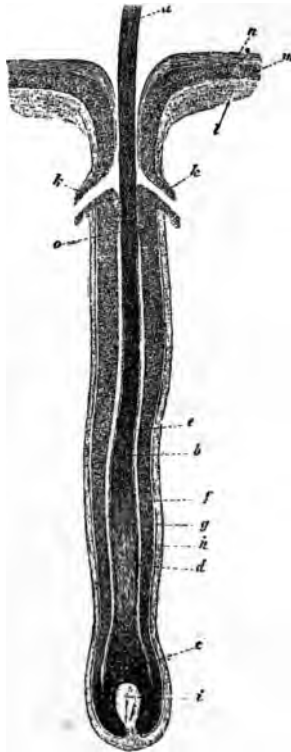
dp dermic papillæ.

m Malpighian cells.

h lower horny layers.

upwards becoming flattened and horny. Each nail grows in a bed, the root and edges being covered by a fold of the

FIG. 58.



Hair-follicle with hair.
(¹⁰ Kölliker.)

a stem.

b root.

c knob.

d cuticle.

e, f inner and outer root-sheaths.

g hyaline layer.

h dermic coat.

i papilla.

k, k ducts of sebaceous glands.

l corium.

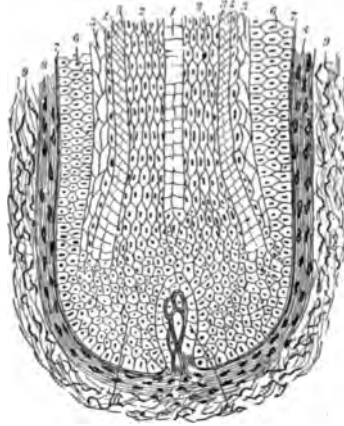
m, n mucous and horny layers of epidermis.

o upper limit of inner root-sheath

skin. Hair is also an epidermic appendage (a few, however, are found in the nostrils, and external auditory canals). Each

hair arises from a small papilla in the bottom of the hair-sac, and, as each decays, a new sac buds from the old one, thus giving origin to a new hair. There may be as many as

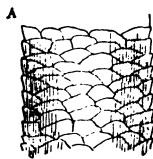
FIG. 59.

*Root of a hair magnified.*

- | | | | |
|-------------|------------------------|----------|--|
| Hair-stem | { 1 medulla. | Sac-wall | { 7 hyaline layer. |
| | { 2 fibrous body. | | { 8 inner dermic coat (corpuscles |
| | { 3 cuticle. | | { arranged circularly). |
| Root-sheath | { 4 epidermic coat. | | { 9 outer dermic coat (corpuscles |
| | { 5 inner root-sheath. | | { longitudinally). |
| | { 6 outer root-sheath. | | { 10 cells of the bulb. |
| | | | { 11 papilla containing blood-vessels. |

1300 hairs to the square inch, e.g. on crown of head ; in most parts they are but slightly developed, being fine, soft, downy, and devoid of colouring matter (but not white) ; this is especially the case in women. When hairs are white, there is an absence of pigment, and a presence of numerous air-bells or

FIG. 60.

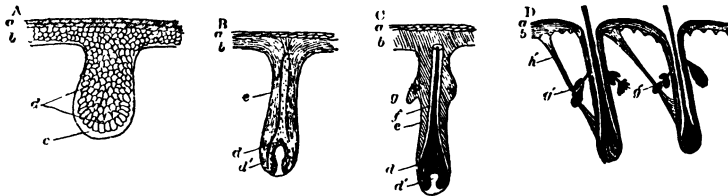


- A surface of a hair showing cortical scales.
 B two separated scales.
 C four cortical cells from developed portion of hair.
 D cells of root-sheath from above.
i, *i'* inner and outer layers of inner root-sheath.
e layers of outer root-sheath.
e' its outer columnar layer.

bubbles in the medulla. Hair has turned white from grief in a single night, and quite grey from excessive heat within a day ; also, I believe, from fright. Their diameter is exceedingly variable, average, perhaps, $\frac{1}{250}$ in. The part of the

hair embedded in the skin is termed the root; the free part, the stem, or shaft. The shaft is sometimes flat, the hair then being curly; sometimes round, the hair being straight. Upon section, the shaft of each hair is seen to consist of (1) the fibrous body of the hair (sometimes enclosing a pithy medulla, and being then called the cortical part), with (2) a cuticle of elongated cells, like imbricated scales arranged in transverse rows, and which overlap like tiles, sloping upwards, sometimes giving the appearance of cross-fibres: besides this, around the root there are the root-sheaths and the sac wall. The root-sheaths, or epidermic coat, consist of (1) the cuticle of the root-sheath, innermost, imbricated,

FIG. 61.



Development of hair.

a horny layers, and *b* Malpighian layers of epidermis. *c* limiting membrane. *d* cells of hair. *d'* papilla. *e* outer root-sheath. *f* inner root-sheath. *g* rudimentary sebaceous glands. *g'* developed ditto. *h* muscles of hair-follicle.

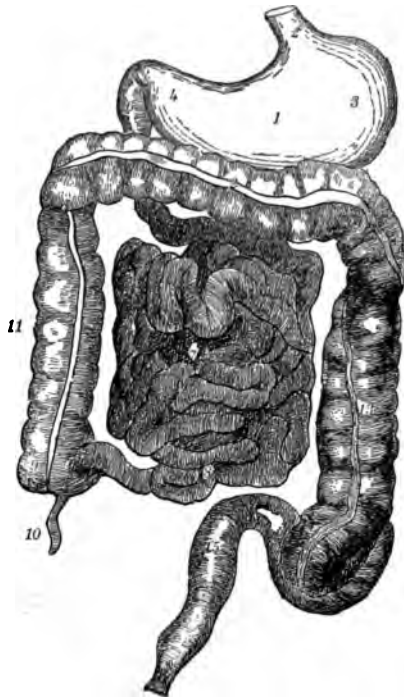
the scales sloping downwards, and interlocking with those of the cuticle, (2) the inner root-sheath consisting of two layers of cells, the inner nucleated (sometimes double); (3) an outer root-sheath very thick, formed by nucleated cells, continuous with the rete mucosum, the outer layer columnar. The wall of the sac consists of (1) an inner hyaline layer, continuous with the membrana propria, (2) the inner and (3) the outer dermic coats, both continuous with the dermis. The hair probably grows by the multiplication of the papillary cells, the upper ones becoming lengthened into fibres: some think that the papilla is covered by a hyaline membrane, continuous with the hyaline layer of the sac wall.

CHAPTER II.

DIGESTION.

33. The digestive organs consist of (1) a long tube, the alimentary or digestive canal (in man about 23 feet in total length, but varying much) which commences at the mouth,

FIG. 62.

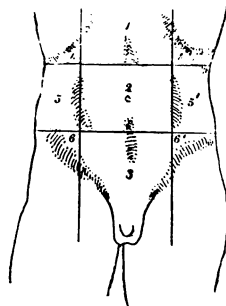


Digestive canal. (The buccal cavity, pharynx, and oesophagus, are not shown).
1 stomach. 2 its cardiac orifice. 3 great curve. 4 pyloric pouch. 5 pylorus. 6 duodenum. 7 jejunum. 8 ileum. 9 caecum. 10 vermiform appendix. 11, 12, 13 ascending, transverse, and descending colon. 14 sigmoid flexure. 15 rectum.

presents an enlargement in its course—the stomach—and ends in a long convoluted tube—the intestines, which may

be divided into a small, but long, upper, and a large, but short lower portion, (2) the liver and pancreas, two large glands, which pour their secretions into this canal. The parts of the alimentary canal, from above downwards, are the mouth, pharynx, œsophagus, stomach, smaller and larger

FIG. 63.



Abdominal regions.

- 1 epigastric.
- 2 umbilical.
- 3 hypogastric.
- 4, 4' right and left hypo-chondriac.
- 5, 5' right and left lumbar.
- 6, 6' right and left iliac.

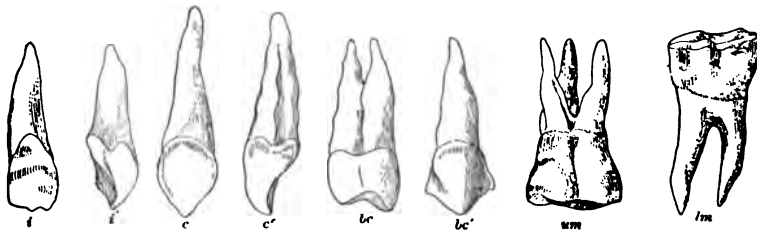
intestines : they are lined throughout with mucous membrane. The greater portion of the digestive organs are found in the abdominal cavity. The *abdomen* is arbitrarily divided into nine regions, the epigastric, umbilical, and hypogastric respectively down the centre, and on either side respectively a hypochondriac, lumbar, and iliac.

34. The mouth may be conveniently viewed as an extensible sac, which serves for the reception of the food to be digested. It is an irregular cavity, bounded by the lips, cheeks, hard and soft palate, tongue, and fauces. At the margin of both lips, upper and under, we see the two ectodermic elements, epidermis and epithelium, passing into and continuous with each other. The roof of the mouth is formed by the palate; the anterior portion, the hard palate, is supported by bone, and has the fore-part of its surface ribbed transversely; the posterior portion, or soft palate, continuous with the other, is a veil of mucous membrane and muscular fibre. The hard palate is simply a passive agent in the mechanical preparation of the food. The posterior part of the mouth is termed the 'fauces,' around the central 'isthmus' of which are, above, the soft palate, from which depends posteriorly a little pendulous body, the uvula; on

either side two membranous folds, the anterior and posterior pillars of the fauces; the tonsils are two almond-shaped glandular bodies on either side of the floor, and between the pillars.

35. The *teeth*, thirty-two in number in the adult, are implanted in alveoli, or sockets, 16 in either jaw. They form two regular rows, without any interspace or diastema, and which meet each other, the lower being slightly within. The

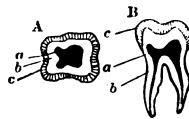
FIG. 64.

*Permanent teeth.*

i upper median incisor (outer aspect). *i'* same viewed sideways. *c, c'* upper canine. *bc, bc'* upper first bicuspid. *um* upper first molar. *lm* lower first molar.

teeth of the right and left sides are precisely similar, and those of the upper and lower jaws nearly so. The visible part of a tooth is called the *corona*—the embedded portion, the *root*—the point of junction of these two, the *neck*. The root consists of one or more fangs. The main mass of a tooth is composed of dentine; its upper part is covered by a layer of enamel, the root by the 'crusta petrosa,' a layer of

FIG. 65.

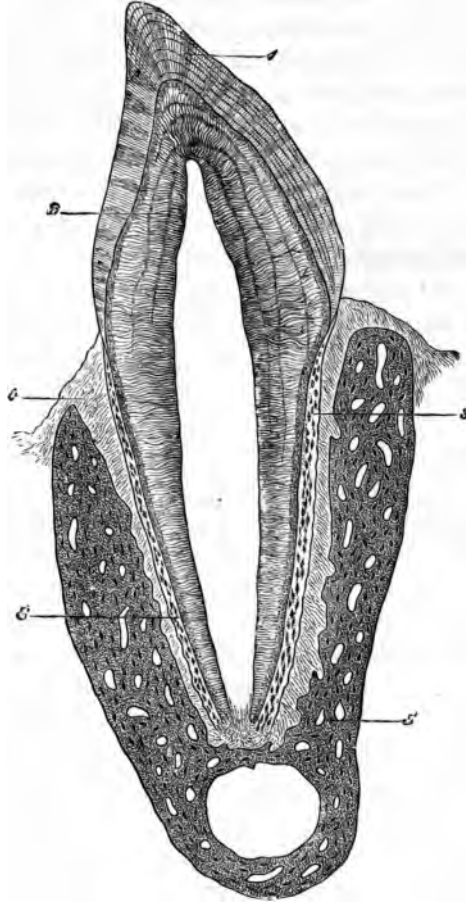
*Section of a molar tooth.*

A horizontal. B vertical.
a pulp-cavity.
b dentine.
c enamel.

cement, which, upon meeting with the enamel, is external to it, bevelling over it, but almost immediately ceasing. The enamel is covered externally by a very thin, tough, horny membrane—Nasmyth's membrane. Each tooth contains a central cavity. Teeth are not bones, but enderonic or dermal appendages; they are probably the sole representatives in

man of the enderonic or dermal skeleton. In man there are two sets of teeth (1), the deciduous or milk teeth (20 in number) which fall out, and are replaced by (2) the perma-

FIG. 66.



Vertical section of premolar tooth (cat. Waldeyer).

1 enamel, showing radiating and concentric markings. 2 dentine, showing tubules and incremental lines. 3 crustra petrosa (cement). 4 dental periosteum. 5 osseous tissue of jaw.

nent teeth (32 in number). Teeth are of three kinds ; incisors, canines, and molars. In each side of each jaw are eight teeth : two incisors, or cutters, situated in front, each with a free cutting edge, and a root consisting of one fang ; one

canine at the corner, being rather more pointed, and with a longer fang fitted for tearing flesh; and five molars or grinders, two smaller ones called bicuspsids, premolars, anterior, or false molars, three larger posterior or true molars. Each premolar has a flattened crown bearing two pointed tubercles or cusps, one external, the other internal; the root consists of one fang slightly cleft. All the teeth described above are very similar in both jaws, and have deciduous predecessors; they often vary slightly in different individuals. The true molars vary slightly in shape; the first has four cusps and three fangs (two outer) in the upper jaw, five cusps (three outer), and two grooved fangs (an anterior and posterior) in the lower; the second molars resemble the first; the third, or 'wisdom teeth,' are more irregular, generally having the fangs blended together into one irregular one; the inner cusps also are blended together in the upper jaw.

FIG. 67.

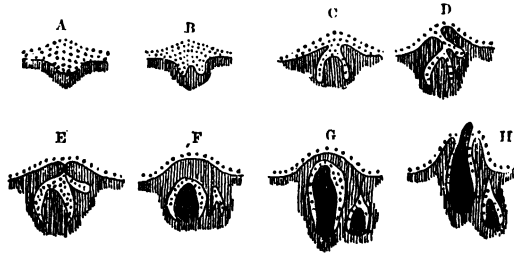
*Four milk teeth.*

- a* lower second molar.
- b* upper first molar.
- c* upper canine.
- d* lower outer incisor.

The milk teeth consist of two incisors, one canine, and two molars in each side of each jaw, the true molars having no predecessors. These teeth resemble their successors with the exception of the last molar, which resembles the first true molar among the permanent teeth, although it precedes the last premolar, as regards origin and situation. The incisors are set in that part which is the pre-maxillary (or inter-maxillary) bones of some animals, the molars in the true superior maxillaries, the canines at the junction of the pre- and superior maxillaries. The development of the milk teeth was formerly described as follows:—A groove, the dental groove, is formed in the mucous membrane of the jaw; in this little papillæ are developed; small partitions arise between, and operculæ or flaps over the papillæ, and these follicles close up, forming the dental sacs. The papillæ are vascular pulpy masses, the dental bulbs or gums en-

closing them : little sacs become developed from the follicles during the formation of the milk-teeth, and, in these, their successors are developed in a similar manner. The external part of the pulp becomes calcified, or rather gives way to the dentinal deposit until only a small portion of the central part of the pulp remains, and in continuation with it is a canal through each fang, there being a hole at the end of each for the transmission of blood-vessels and nerves ; these openings finally become obliterated, the pulp wastes away, leaving a cavity, and the tooth decays or falls out. The fangs of the deciduous teeth after a time become absorbed, and so the tooth is easily pushed out by its successor, i. e. is 'cut.' It would, however, appear from modern observations that in-

FIG. 68.

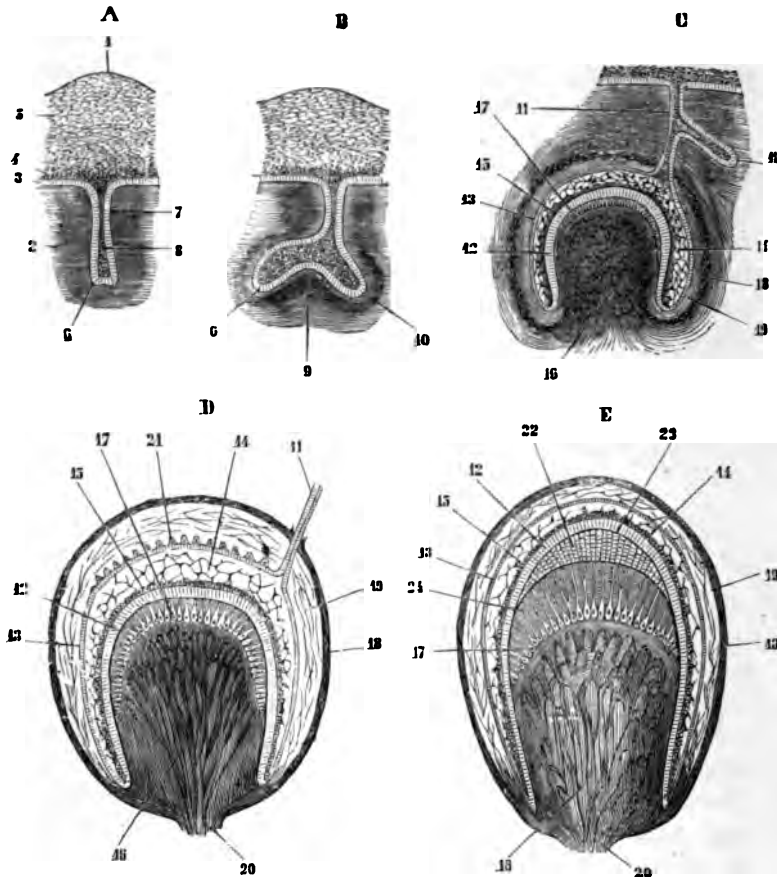
*Development of the deciduous teeth:*

A, B, C, D, E, F, G, H represent successive stages. The dotted portions are the epithelium with its developments, the shaded portion is mucous membrane. The groove, papilla, operculæ, cavity of reserve, deciduous tooth and its eruption, and the reserve permanent tooth are seen.

stead of partitions and operculæ, the teeth are thus formed. The mucous membrane of the gums is covered by the primitive band—a stratified cellular layer—the lowest layer differing ; a depression forms in the mucous membrane, and this involution gradually becomes surrounded and enclosed, forming the enamel germ, whilst the dental papilla presses against it from below ; from the pedicle proceeds another little projection, which also becomes shut off, to become in time the corresponding permanent tooth. The three permanent molars are derived originally from one sac, which gives off the second, and this the third. The outer cells of the enamel germ form epithelia, the cells of the middle portion of the enamel organ send out branched processes which

unite to form a network; the cells of the lower layers remain rounded; of the epithelial layer facing the dental pulp, be-

FIG. 69.



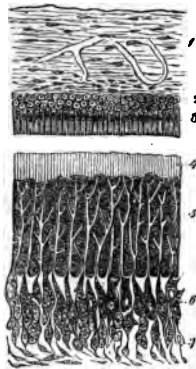
Semi-diagrammatic views of the development of the teeth. (Beaunis et Bouchard.)

A first appearance of the enamel organ. B first trace of the dental papilla, &c. C more advanced stage. D dental germ completely formed. E ossification of the dental germ; appearance of enamel and ivory. 1 dental elevation. 2 mucous membrane. 3 deep epithelial layer of cylindrical cells. 4 middle layers of rounded cells. 5 upper layers of flattened cells. 6 germ of enamel organ. 7, 8 its external and internal parts. 9 dental papilla commencing to push upwards. 10 first traces of dental sac. 11 pedicle of attachment (finally disappears). 11' first trace of enamel organ of permanent tooth. 12 enamel forming cells. 13 external enamel cells. 14 enamel pulp (developed from 6). 15 germinative cells of pulp. 16 dental papilla. 17 dentine cells. 18, 19 external and internal parts of dental sac. 20 pedicle of papilla giving passage to nerve-fibrils and capillaries. 21 enamel papillae. 22 enamel prisms. 23 so-called preformative membrane. 24 dentine, with dentine tubules.

come columnar, and the enamel develops either (1) from these cells by transformation of intercellular substance, or

(2) by deposit from their posterior surface. A space sometimes appears between the cells and the enamel, and in it is often found a jelly-like membrane—*membrana præformativa*—probably an artificial exudation: those who consider it to be a membrane, look upon the enamel as developed (3) from the upper part of the pulp. The enamel cells finally disappear; the enamel develops outwards, the dentine inwards. The dentine arises from the transformation of the ‘odonto-

FIG. 70.



Section of part of developing tooth. (From Stricker's "Histology.")

1 enamel pulp. 2 rounded cells. 3 enamel-forming epithelium (between this and the dentine is a space sometimes filled with a jelly-like substance—*membrana præformativa*). 4 formed dentine. 5 dentine in process of formation showing tubules. 6 odontoblasts sending processes into the tubules. 7 dental pulp.

blasts,’ the outer layer of elongated pulp cells, which send processes outwards, and the deposit either takes place between the cells, or else the peripheral portion of the cell-contents becomes transformed, the nuclei and part (or all) of the cell-contents lining the tubules, either several cells uniting to form a tubule, or else the nuclei gradually receding inwards as calcification proceeds. The ages at which teeth are cut is as follows:—

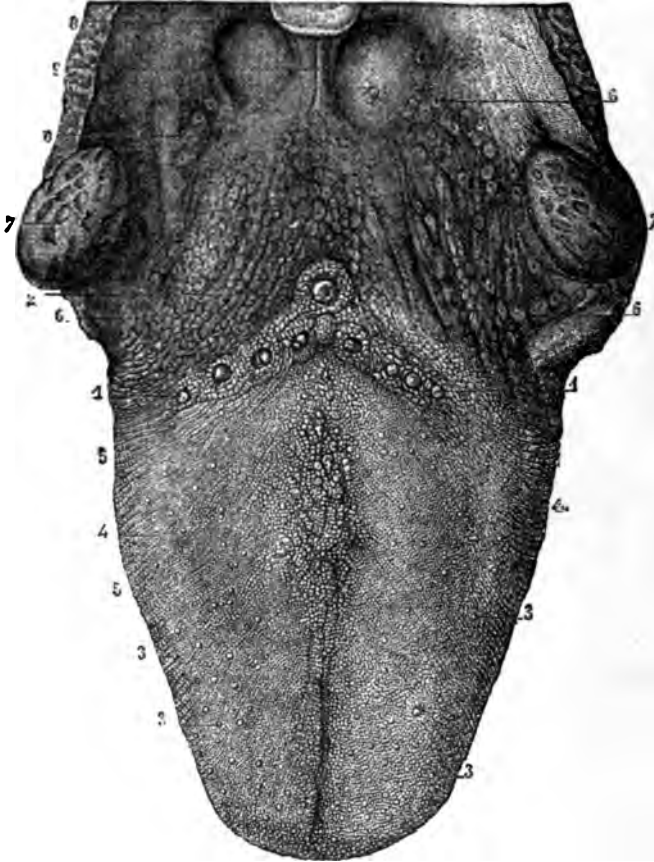
<i>Deciduous.</i>		central i.		lateral i.	ant. m.	c.	post m.		
No. of months after birth.		7		9	13	16		24	
<i>Permanent.</i>		1st m.	mid. i.	lat. i.	1st p.m.	2nd p.m.	c.	2nd m.	3rd m.
No. of years.	6½	7		8	9	10	11	12	17

The lower generally slightly precede the upper; it frequently happens that the third molars never appear.

36. The tongue is a muscular body, capable of movement in all directions. It occupies the floor of the mouth and fauces, and has its surface covered by numerous small

risings, or papillæ, which subserve taste. The papillæ are of various kinds: (A) simple or hemispherical, which bestud the whole of the tongue, as well as covering the other papillæ:

FIG. 71.



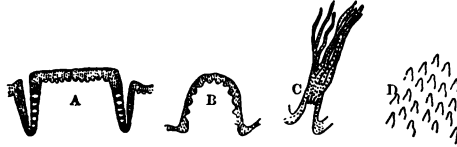
The tongue (dorsal surface). (Sappey.)

1, 2 calyciform or circumvallate papilla (2 "foramen cæcum"). 3 fungiform papillæ.
4, 5 filiform papillæ in rows. 6 mucous glands. 7, 7 the tonsils. 8 part of epiglottis.
9 frenum of the epiglottis.

(B) compound of three kinds; (1) calyciform or circumvallate, eight to fifteen in number, of a conical shape, embedded in hollows, form a V-shaped figure, apex backwards, near base of tongue; (2) fungiform (about 200, 160—290), much smaller and having contracted bases, scattered over anterior

$\frac{2}{3}$ of tongue; (3) filiform, coniform, or corolliform, in rows, the smallest and most numerous, of various shapes, usually having the epithelium at the top (very thick, and) branching

FIG. 72.



A section of the circumvallate papilla; taste-cones are seen in its side walls, and simple papillae in its upper wall. B a conical papilla. C a filiform papilla. D simple papillae (very much magnified).

into many long hair-like filaments. They are also scattered over anterior $\frac{2}{3}$ (being most numerous near the tips), a few also being found near the base.

37. The food is kept under the teeth, in order to be cut up and triturated, by means of the tongue (which also of itself separates the softer portions), on the interior, and of the lips and cheeks on the exterior: this process constitutes mastication. The jaws move in all directions to a certain degree, but chiefly vertically. The food in the meanwhile becomes soaked with saliva, the produce of the salivary glands. Saliva is an alkaline fluid, composed of 994 water, 6 solids, including ptyalin, sulphocyanide of potassium, certain fixed salts, &c. Its chief active principle is ptyalin, which acts (weakly) upon hydro-carbons, especially starches, converting them into dextrine, grape-sugar, or lactic acid, and defending them from the acidity of the stomach. The conversion of these substances occupying from two minutes to four hours. The great use of saliva is the moistening of the food, adding from 30—100 per cent. (3·7—120), to the food ingested, the amount depending chiefly upon the dryness (increasing with it); but the amount secreted and swallowed is not always in exact proportion to that absorbed, e. g. toughness of food increases salivary flow; sapidity also does. About 3½ lbs. is daily secreted: sp. g. 1·114—1·120. It is chiefly secreted by three pairs of compound racemose glands, situated symmetrically. (1) The parotid glands, the largest, behind the lower jaw, and in front of the ear: each empties

by Stenson's (or Steno's) duct through the cheek opposite the upper second molar. (2) The submaxillary, under the angles of the lower jaw: each opens by Wharton's duct under the frænum of the tongue. (3) The sublingual

FIG. 73.

*The salivary glands.*

p parotid gland. *s* Stenson's duct, opening opposite 2nd molar. *sm* submaxillary gland. *w* Wharton's duct. *s* sublingual gland with several ducts. *m* masseter muscle. *t* tongue.

FIG. 74.



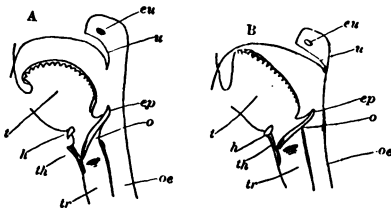
Part of parotid gland injected, showing the acini, at a partly denuded.

beneath the tongue opening by several ducts (those of Rivinus) usually about fifteen, some of which open into Wharton's duct. The secretion of the parotids is most watery, that of the submaxillaries least so. Besides these, there are numerous small racemose glands—e.g. buccal, in the various parts of the mouth; and in the tonsils (and œsophagus) are very small solitary glands, which sometimes surround mucous follicles, especially in the tonsils; the probable function of the racemose glands is to secrete simple mucus. The larger glands each consist of numerous lobules of the typical glandular structure. The epithelium is, however, double, the cells of the free layer having no walls. The nerves terminate in the nuclei of the glandular cells, and in terminal ganglionic cells sending processes to the nuclei.

38. The lubricated bolus of food, when fully prepared, passes into the pharynx (*vide infra*); the soft palate and uvula at the same time are drawn upwards and backwards against the posterior wall of the pharynx, which comes a little forward; the posterior pillars of the fauces also contract, meeting each other and the uvula, thus closing the communication with the nasal passages; the entrance of the larynx is closed as follows: the os hyoides is brought upwards and

forwards beneath the tongue, which is pushed backwards; at the same time the larynx and wind-pipe ascend, and the epiglottis is pushed downwards by the pressure of the tongue, and by the contraction of a few muscles, closing the orifice as it were by a trap-door; the tongue, being applied to the roof of the mouth pushes the bolus backwards into

FIG. 75.

*Deglutition.*

A parts in a state of quiescence.
B during swallowing.

t tongue.
h hyoid bone.
th thyroid.
tr trachea.
oe oesophagus.
o opening of the larynx.
o' the same closed.
ep epiglottis.
u soft palate and uvula.
eu opening of the Eustachian tube.

the pharynx, and from thence by its reflex contraction into the oesophagus; the above parts resume their natural position directly. The whole of this process (great part of which is reflex) is termed deglutition or swallowing. The food passes down the oesophagus, or gullet, and then enters the stomach.

39. The pharynx may be looked upon as a tube ($4\frac{1}{2}$ in.

FIG. 76.

*Antero-posterior vertical section of part of the head.*

1, 1 outer wall of right nasal fossa. 2 orifice of Eustachian canal. 3 uvula. 4 orifice of parotid gland. 5 anterior pillar of fauces. 6 tonsil. 7 posterior pillar. 8 epiglottis. 9 opening of larynx. 10, 10 pharynx. 11 oesophagus. 12, 12 hard palate. 13 soft palate. 14 tongue.

long, 2—1 in. diam.) with the following openings:—At the top the two nasal; in front the oral, and below this the

laryngeal one; at the bottom, the entrance into the œsophagus, with which it is continuous. The œsophagus is a slightly bent tube (9 long, 1 diam.) which passes through the diaphragm, and ends in the cardiac end of the stomach.

Fig. 77.

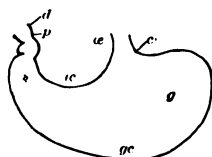
*Posterior view of the pharynx.*

1 posterior nares. 2 mouth of Eustachian valve. 3 vomer. 4 uvula. 5 soft palate. 6 base of tongue. 7 epiglottis. 8 opening of larynx. 9, 9 back of trachea. 10 back of œsophagus. 11 its walls drawn apart. 12 walls of pharynx drawn apart. 13 posterior pillar of fauces. 14 buccal cavity.

Its general structure and muscular action resemble those of the intestines, but it also contains in its upper part some striated fibre. It collapses when empty, displaying longitudinal wrinkles.

40. The stomach is a bag capable of containing about four pints of fluid. It is situated on the left side of the body in the upper part of the abdominal cavity, within the thorax, and beneath the diaphragm. When empty it collapses (as do all the parts of the digestive canal), and its under surface is rugose—the rugæ, plicæ, folds, or wrinkles running longitudinally. When distended, it presents a lower convex border, the greater curve, and an upper concave one, the lesser curve. Sometimes when nearly or quite empty, it is

Fig. 78.

*Diagrammatic outline of stomach.*

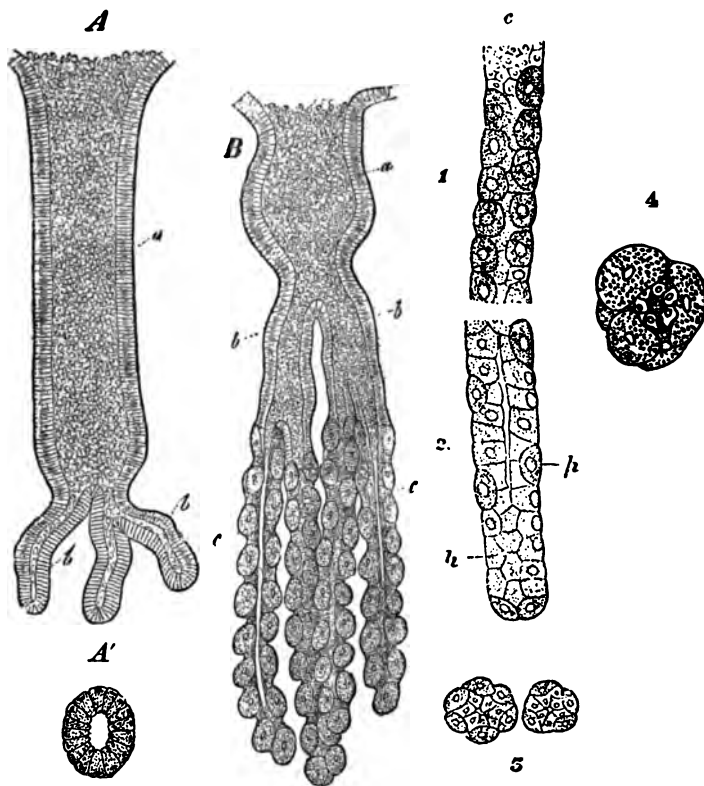
a œsophagus. c cardiac orifice. g greater or cardiac pouch. ge greater curvature. l lesser curvature. s smaller or pyloric pouch. p pylorus. d duodenum.

slightly constricted near the middle; the upper and larger pouch is the cardiac, the lower the pyloric pouch. The

cardiac orifice, leading into the œsophagus, has no special apparatus for closing it; but the pyloric orifice, leading into the commencement of the small intestine, is guarded by a ring-like reduplication of mucous membrane and sphinctral muscular fibres, sometimes called the pyloric valve. When the stomach is filled with food, the both orifices are closed, and a constriction commences at the cardiac, and runs along like a wave to the pyloric end, pushing the food in contact with the walls before it, the returning portions of the food travelling back by the axis to the cardiac end; according to others, the food passes down the greater curve, and up back by the lesser. This process keeps on for various lengths of time, each revolution occupying from one to three minutes. At first the whole stomach is active, but afterwards it becomes constricted at the notch, producing the so-called hour-glass constriction, and the muscular action is nearly or quite confined to the pyloric pouch. In the meanwhile the gastric glands pour out their secretions, and by the above movements the food becomes saturated with it. Upon the inner surface of the stomach are seen myriads of small polygonal pits—alveoli ($\frac{1}{100}$ — $\frac{1}{200}$ diam.), into the floors of each of which six or eight (or more) gastric tubuli open; the alveoli are larger and more oblong nearer the pylorus than elsewhere. The alveolar septa near the pyloric end develop fringed processes—rudimentary villi. The gastric glands, tubuli or follicles are minute tubes, mostly simple at the cardiac end, growing more complex till they become multilocular tubes further down. The gastric glands are of two kinds: the mucous and the peptic glands: (many intermediate forms are found). The mucous glands are found in greater abundance near the pylorus; they consist of a tube which divides below into several short tubules. They are lined by columnar epithelium continuous with that of the stomach; in the lower parts the cells are more cubical, and resemble the peptic 'central' cells. The peptic glands consist each of a short tube, which divides below, and almost immediately afterwards the ultimate tubules lose the columnar epithelium; the upper part of each tubule consists of the large coarsely-granular peptic cells, the lower part of finely-granular central cells, with

here and there outside them a peptic cell ; very probably the central cells become smaller, and line the peptic cells in the upper part, being continuous with the columnar cells. There are about 5,000,000 glands ($\frac{1}{40}$ long, $\frac{1}{400}$ diam.), and they secrete the *gastric juice*, a slightly acid fluid, which acts upon

FIG. 79.



Gastric glands. (After Kölliker, &c.)

A mucous gland. a trunk. b, b caeca.

A' transverse section of a caecum.

B peptic gland (Dog). a trunk. b branches. c caeca. 1 neck of caecum. 2 deeper part of caecum. 3, 4 cross-sections of caeca, showing glandular peptic cells and small central lining cells.

proteinaceous compounds, converting them into peptone or albuminose, capable of easy absorption. More acidity is required for digesting vegetable than animal fibrin. It possibly, but not probably, acts upon starches and sugars. It is composed of .994 water, .003 pepsin, some salts, and free

hydrochloric acid (lactic acid, when found, being a secondary product). Pepsin, a kind of organic ferment, is the chief active principle; whether the mucous or peptic glands secrete it is not known—probably the latter, but very possibly both. About 14 lbs. (7—30) of gastric juice are secreted daily: sp. g. 1.114—1.120. When the food is reduced to a pulpy mass, the proteinaceous elements being sufficiently digested, the pyloric valve allows its passage into the intestine. At first, the valve for a time (22 min. upwards) allows no food whatever to pass, then the soft portion, then relaxes entirely, and allows the whole of the residue to escape. The time taken by the stomach in thus digesting the food varies from 1—5½ hours according to the nature of the food. Rice, tripe, and raw eggs take 1 hour; fish 1½; raw milk, 2¼; animal food generally 2½—3½, boiled taking less time, but being less nutritious than roasted; bread, 3½; pork, 5¼.

41. The œsophagus, stomach, and both intestines have fundamentally the same structure; (1) an outer serous coat (in the stomach and intestines, derived from the peritoneum) consisting of an epithelium of flattened hexagonal cells, supported by basement membrane, and areolar tissue. (2) A middle muscular coat of non-striated muscular fibre. This coat is double, and consists of an outer 'longitudinal' layer of fibres running longitudinally, and an inner thicker 'circular' layer of fibres running transversely; the circular layer is very thin in the œsophagus. Besides these, at the cardiac end of the stomach, there is between the circular layer and the mucous coat a layer of oblique fibres. (3) An inner mucous coat, consisting of sub-mucous areolar tissue, basement-membrane and columnar epithelium.

42. The lesser intestine is a canal about 16 ft. long, or more, and about 1¼ in. diam. It is divided into three parts. (1) Duodenum, about 10 in. in length. The hepatic and pancreatic ducts pour into it together by an united orifice about ⅓ down the tube. (2) Jejunum, about 6 ft. long. (3) Ileum, 9 ft. long. The duodenum is rather the widest, and the ileum the narrowest portion.

43. The mucous membrane of the lesser intestines is thrown into transverse folds, the *valvulæ conniventes*, which run

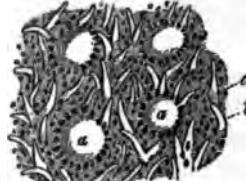
about $\frac{1}{3}$ round the canal; they serve to increase the absorptive area, and retard and separate the chyme. The mucous membrane of the whole lesser intestine, both walls and folds,

FIG. 80.



Wall of lesser intestine. Showing the valvulae conniventes.

FIG. 81.

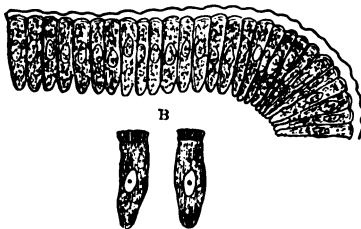


Mucous surface of lesser intestine (ileum). (Kölliker.)
a Peyer's glands. b villi. c mouths of Lieberkühn's follicles.

is furnished with little slender papillary processes, the absorptive villi, and with numerous secretive glands. There are about 4,000,000 villi, $\frac{1}{12}$ — $\frac{1}{30}$ in. long, in section somewhat triangular ($\frac{1}{100}$ by $\frac{1}{200}$). The epithelial cells have seamed outer walls, and among them are certain globular 'goblet'

FIG. 82.

A



Epithelium of a villus. (Rabbit. Kölliker.)

A columnar epithelial cells showing a membrane or border passing over their free ends.

B cells showing the striation of the border.

FIG. 83.



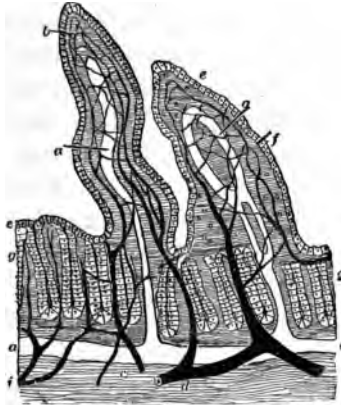
A goblet-cell. (After Klein.)

A little of the cell-substance together with the nucleus remains in the lower portion.

cells, devoid of an outer wall. One straight lacteal, or two or more anastomosing ones, or rarely a network with one root, run up the centre of each villus. The rudimentary villi in the pyloric end of the stomach are devoid of lacteals. The food enters the duodenum in the state called *chyme*, a greyish, pulpy, slightly acid mass consisting of more or less dissolved proteinaceous compounds, slightly dissolved carbohydrates, and undissolved fatty substances. By the admixture, however, of the bile (the secretion of the liver), the pan-

creatic fluid, and the intestinal juices, it becomes converted into what is badly called *chyle*, which has a whitish milky

FIG. 84.



Section of intestinal mucous membrane, with two villi. (Rabbit. After Frey.)
a lacteals. *b* blood-capillary network. *c* arterioles. *d* small vein. *e, e* epithelium.
f retiform tissue. *g* Lieberkühn's follicles. *i* submucous layer.

appearance, and is alkaline. The chyme and chyle should be spoken of respectively as stomachic and intestinal chyme, and the term chyle restricted to the absorbed portion. The chyme then passes down through the intestines in consequence of the contraction of the non-striated fibre cells in its walls, the constriction forming a wave which travels downwards, forcing the chyme onwards: this is termed the peristaltic or vermicular action of the intestines, and is common to both intestines and the œsophagus (and the stomach in a modified way): it is due to the contraction of the succeeding parts, the longitudinal fibres, alternately elongating and contracting, act like putting on the fingers of a glove, whilst the circular fibres, contracting immediately behind, lessen the circumference of the canal, and push its contents onwards. Food is from 3 to 6 hours in passing through the small intestines. In intestinal chyme we find that all the digestible substances become dissolved, the fatty ones being formed into an *emulsion*, in which the fat is separated into very minute particles which float in the watery basis like the butter-globules of milk.

44. It will be well now to consider the phenomenon of absorption. All liquids, whatever their specific gravity, have a tendency to become mixed together; this is termed liquid diffusion. Osmosis is the process by which two fluids separated by a membrane or other porous substance, penetrate it and mix together—the lighter fluid permeating it most readily: thus, when two fluids of different sp. g. are separated by a membrane, the lighter passes through, and becomes diffused among the heavier, an appreciable quantity of which also passes into the lighter. A fluid passes into a vessel by *endosmosis*, out of it by *exosmosis*. Bodies may be divided according to their diffusibility into two classes, those whose solutions are highly diffusible being termed crystalloids, those slightly so, colloids. Crystalloids are generally chemically active, e.g. sugar, alkalies, salts. Colloids possess a low degree of activity, e.g. starch, gum, albumen, &c. Colloids are easily permeable, and thus are most suitable for forming organized bodies. Possibly a colloid molecule is an aggregation of smaller crystalloid molecules. There are no crystals in the body (or in the blood during life); all substances during their useful period assuming a colloid form. Salts and acids convert colloids into crystalloids, in order to be absorbed, these in the alkaline blood again resuming their colloid form. The use of the saline and mineral constituents of foods is thus to promote absorption (and the removal of effete matter). Alkalies seem to attract acids, and we find accordingly that the chyme is more acid than the blood. The amount absorbed depends partly on the general plethora of the system, being in inverse ratio to it. Digestive absorption takes place in both intestines (chiefly the lesser), and to a slight extent in the stomach also. Both blood-vessels and lacteals absorb nutritive substances, the lacteals absorbing chyle only, the blood-vessels anything suitably diffusible, since they possess little or no ‘selective power,’ which term comprises certain unknown laws of diffusibility, influenced to a slight degree by ‘vital force.’ Digestion seems to be chemically a hydrolytic decomposition, water being added. Starch becomes converted into dextrine, then into glucose, cane-sugar changed into

grape-sugar and lactic acid. Starch and dextrine $C^{12} H^{20} O^{10}$ + water $H^2 O =$; Cane sugar $C^{12} H^{22} O^{11}$ + water $H^2 O =$; Grape sugar, glucose, or lactic acid $C^{12} H^{24} O^{12}$. Hydrocarbonaceous products are absorbed from the mouth to the upper part of the small intestine inclusive. Albuminoids are *mostly* changed into peptones, and are absorbed in small intestine and cæcum. Fats are only emulsified, and are absorbed in both intestines. Small portions of the glucose, fat, &c., are not absorbed, but become changed into other principles, e. g., fat into glycerine and fatty acids.

45. The greater intestine is a canal about 5 ft. long, by 2—3 in. diam. It has its walls puckered into sacculi, arranged in three rows, owing to the longitudinal muscular fibres being in three bands, which are shorter than the rest of the walls. It is divided into three parts—the cæcum, colon, and rectum. The greater part of the chyle having been absorbed, the residue enters the large intestine through the ileo-cæcal valve—a double valve—which forms the line of demarcation between the cæcum and colon, these two parts being continuous. The cæcum is about 3 in. long, and ends below blindly. The vermiform appendage is a small tube of from 2—6 in. in length, $\frac{1}{4}$ in. diam., of the same structure as the rest of the intestines, and which opens by an imperfect valve into the blind end of the cæcum, of which it should probably be considered as a rudimentary continuation. The colon is about 4 ft. long, and consists of four parts; an ascending, a transverse, a descending portion, and an S-shaped ‘sigmoid flexure:’ the latter passes into the rectum, a straight non-sacculated gut, 7 in. long, which communicates with the exterior by an orifice termed the anus. The anus is surrounded by two rings of striated muscular fibre, termed the external and internal sphincter muscles. In the great intestine the food is lifted in the ascending portions by the peristaltic action from one saccule to another, in the descending portion these saccules serve as shelves to pack the fæces on, thus relieving the pressure upon the anus. These saccules cause the ‘scybalæ,’ or rounded masses characteristic of sheep-dung, sometimes seen in the human fæces. The chyme again becomes acid in the large intestine.

There are no villi or other special organs of absorption in the large intestine, where the remainder of the chyle is absorbed,—the useless and undigested portion of the chyme being got rid of by the act of defæcation, which is chiefly produced by the contraction of the abdominal muscles; thus it will be seen that both the ingress and egress of food-substances are guarded by reflex voluntary-muscles, which are partly under the control of the will. The time that the chyme remains in the large intestine varies very much—usually 6—24 hours, and defæcation normally occurs about once daily. A vegetable diet, as may be expected, tends to cause constipation, hydro-carbons being digested in the intestines; for the same reason herbivorous or vegetivorous animals have very long intestines, twenty-eight times the length of body in sheep, only three times in the insectivorous mole and some carnivora, seven times in man. The fæces are composed of 73 per cent. water, 6 soluble, and 7 insoluble food substances, 14 insoluble excreta. Their peculiar disagreeable odour is acquired in the large intestine, and is probably due to the presence of partially oxidated tissues secreted by the large intestine, and not to decomposition of imperfectly digested portions of food. Certain gases are also found in the alimentary canal; these are mostly produced by the decomposition of the food, and of the fluids excreted. The gas varies in different parts, the percentage of the principal gases is as follows:—

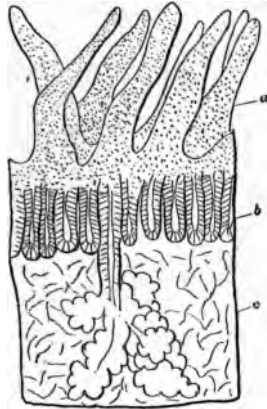
	Stomach.	Lesser Int.	Great Int.
Oxygen .	11	—	—
Carbonic acid	14	24	43
Hydrogen .	—	55	—
Nitrogen .	70	20	50

About 5 per cent. of carburetted hydrogen, and a little sulphuretted hydrogen are also found in the large intestine. Both fæces and gases differ considerably according to the food.

46. In the walls of the intestines are embedded numerous small glands of three varieties. (1) The intestinal tubuli, follicles or crypts of Lieberkühn, which are simple tubes of columnar epithelium and basement membrane, blind in-

wards, resembling the simple gastro-mucous glands. They are exceedingly numerous, and are found throughout both intestines ($\frac{1}{10}$ — $\frac{1}{80}$ diam.) (2) The duodenal or Brünner's glands, are small compound racemose glands ($\frac{1}{10}$ diam.)

FIG. 85.

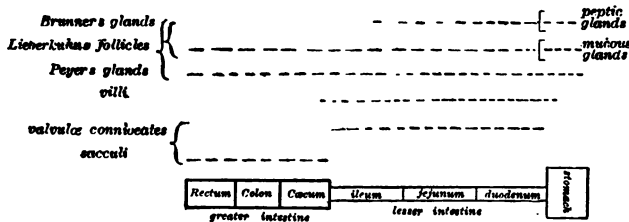


Section of part of intestine wall (duodenum).

a villi. b Lieberkühn's follicles. c a Brünner's gland in the submucous tissue.

resembling lobules of salivary glands in their structure. (3) The lenticular, or solitary glands, or closed follicles, are found throughout the digestive canal; each consists of a bi-convex or lens-shaped capsule ($\frac{1}{3}$ diam.) of rather fibrous

FIG. 86.

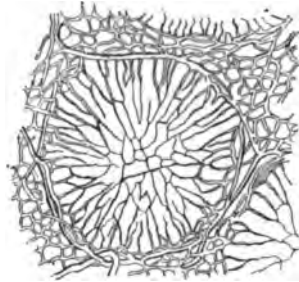


Distribution of glands, &c. The thicker the line the more frequent their occurrence.

basement membrane, containing cells, free nuclei, and fluid, the cells and nuclei probably being derived from an original epithelial lining. Minute blood capillaries send numerous loops into them. They have generally no opening, but burst when they discharge their contents into the intestinal

canal. When these glands occur in clusters they are termed agminated glands, and the clusters 'Peyer's patches.' They generally disappear in old age, and their functions are unknown; they seem to be 'ductless' rather than secretive glands. The glands of Brünner and Lieberkühn's follicles

FIG. 88.

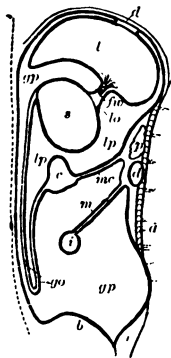


Capillary network of a Peyerian capsule seen in transverse section.

secrete the intestinal juice, *succus entericus*, or *s. intestinalis*, which is slightly alkaline, and acts upon all the food constituents (least upon fats). About 7 oz. are secreted daily: sp. g. 1.112. The secretion of the Lieberkühn's follicles of the large intestine apparently varies from that of the smaller.

47. The *peritoneum* is a serous membrane, which lines the

FIG. 89.



Diagrammatic outline of the peritoneum.

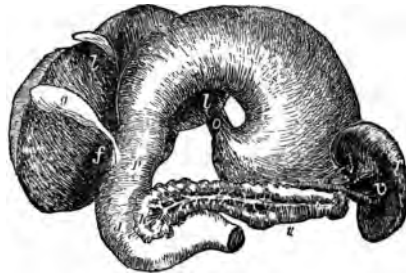
gp greater, and *lp* lesser peritoneal spaces.
fw foramen of Winslow.
go greater omentum, *lo* lesser omentum.
d diaphragm.
l liver.
mc meso-colon.
m mesentery.
s stomach.
c colon.
i ileum.
p pancreas.
d duodenum.
b bladder.
r rectum.
a aorta; behind it, the vertebral column.

whole cavity of the abdomen, and is reflected over nearly all the organs situated below the diaphragm, being more or

less loosely attached to all the surrounding surfaces, serving to hold the intestines and other organs in situ, and furnishing them with more or less complete coats. It also sends off three broad processes—*omenta*, which serve as ligaments to hold parts in position—the great or gastro-colic, the lesser or gastro-hepatic, and the gastro-splenic omenta, and several smaller ones, termed ligaments. The *mesentery* is the portion which encloses the small intestines, and attaches them to the spine, the duodenum excepted, this part having no mesentery, and being but partly covered with peritoneum (as a serous layer).

48. The *liver* is a large, flattish, reddish-brown organ of about 50 oz. (—53 oz., 48—60, being the largest viscus in the body), and divisible into five lobes. It is situated immediately beneath the diaphragm, and beneath the right and part of the left lungs, overlying the pyloric or right end

FIG. 90.



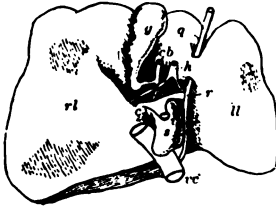
Stomach, liver, pancreas, and spleen. (After Tiedemann.) (The stomach and liver turned up.)

liver. *g* gall-bladder. *f* common bile duct. *s* stomach. *o* pylorus. *d* duodenum. *r* spleen. *v* hilus. *h, e, i* pancreas, partly dissected to show the duct and its branches. *h* head. *t* tail.

of the stomach. It possesses a fibrous coat, called Glisson's capsule, a reflection of which enters and lines the portal canal and its ramifications, which afford passage for the portal and hepatic veins and hepatic duct, and their larger branches. It is also for the most part invested (externally to Glisson's capsule) by the peritoneum, G.'s capsule being at these parts very thin, if not sometimes absent. The parenchyma, or gland-substance, consists of (1) a mass of granular nucleated polyhedral cells ($\frac{1}{1000}$ diam.), which are clustered into minute lobules termed acini ($\frac{1}{18}$ in. diam), all

held together by areolar tissue continuous with its proper coat (G's capsule); (2) a plexus of blood-capillaries with its arteries and veins; (3) the hepatic duct with its branches, which carry away the bile. The liver is supplied with impure blood by the vena portæ, or portal vein, which forms,

FIG. 91.

*Under surface of liver.*

rl right lobe. c caudate lobe. s Spigelian lobe. q quadrate lobe. ll left lobe. cc vena cava. v vena portæ. h hepatic artery. r round ligament of liver. cb common bile duct. g gall-bladder.

FIG. 92.

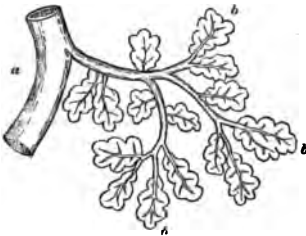
*Ideal diagram of liver—under surface.*

(After Flower.)

rl, rl right lateral lobe. c caudate lobe, s Spigelian lobe. rc right central lobe. g gall-bladder. lc left central lobe. ll left lateral lobe. cc vena cava. dv ductus venosus. p portal fissure.

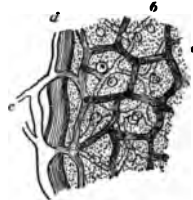
as it were, a liver-artery, and which conveys all the venous blood from the stomach, pancreas, spleen, and (with a trifling exception) the intestines; from which impure blood the bile is probably formed. It is supplied with pure blood by the hepatic artery; the pure blood serves for the nourishment of the parenchyma, though the hepatic artery also helps to

FIG. 93.

*Hepatic vein and lobules. (After Kiernan.)*

a hepatic vein, with b biliary lobules upon its terminal intralobular branches.

FIG. 94.

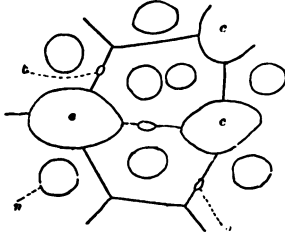
*Small portion of hepatic lobule.*

The bile-capillaries are seen as a network—some underlying the hepatic cells between the meshes. a bile capillaries. b a hepatic cell. c a small bile duct. d a blood capillary.

supply the intralobular capillary plexus: its branches are interlobular. The hepatic veins carry the blood away; the acini appear to be arranged like berries upon their ultimate branches; there are two large, and several smaller veins. The ultimate branches of the portal vein traverse the inter-

lobular spaces forming a network, the small hepatic veins being central or intralobular: between these two sets are the usual capillaries, which are chiefly intercellular and intralobular, and unite together both systems, and also neighbouring lobules. The lymphatics furnish some of the veins (perhaps all, and the capillaries also) with an extra coat, as in the brain, the blood-vessel running through the centre of the lymphatic. The smaller branches of the hepatic duct form an interlobular network, and also ramify in the outer parts of the lobules, its ultimate terminal branches ending (blindly, or more probably) in an intralobular intercellular capillary network of cylindrical canals, which possibly have

FIG. 95.



Diagrammatic section of liver substance.
(After Hering.)

c, c, c blood-capillaries. *b, b* bile capillaries. *n* nucleus of a hepatic cell. (Two cells and portions of several others are seen.)

FIG. 96.



Transverse section of hepatic lobule.
Showing capillary network: in centre hepatic vein; at the circumference, branches of portal vein and smaller branches *a, a* of hepatic artery.

proper walls—a very delicate membrane continuous with the basement membrane of the larger capillaries enclosing columns of cells; the epithelial cells of the ducts seeming to become converted gradually into the glandular cells, and filling up the tube. The cell-walls around the bile-capillaries seem to be thickened: the capillaries generally lie between two cells, and not at the angles. In the ducts, which are distinguishable as such, the epithelium is tessellated. According to some, gland-capillaries (conveying secreted fluid) have also been seen in the pancreas, the lachrymal, salivary, and lactic glands. The secretion of bile being continuous, that formed between the times of digestion is diverted by

and stored up in the gall-bladder,—the hepatic duct of the liver, and the cystic duct of the bladder uniting at an acute angle to form the common bile duct, or choledoch.

49. The *gall-bladder* is a small pear-shaped sac, which has a honey-combed appearance inside, and is situated beneath the right lobe of the liver. When full it contains from 1 to 2 oz. of bile, which it pours out during digestion, when the food enters the duodenum. Its duct (the cystic), when full, appears spirally twisted.

50. The *liver* is generally looked upon simply as a secretory gland; but it is a secretory, excretory, blood-elaborative and blood-alterative organ, and is, to a certain extent, a lung complementary. Its most definite function is (A) the secretion of bile. *Bile* is an alkaline fluid of a transparent greenish-yellow. It consists of .86 water, its solid constituents being its active principle bilin (which is divisible into taurocholate and glycocholate of soda), also cholesterin (a peculiar fat), other fatty substances, pigments, salts, and mucus. The colouring matter consists of biliverdin (green) and biliphœin or cholepyrrhin (brown), the latter predominating in man. About 3.5 lbs. is secreted daily, sp. g. 1.020; it is secreted in the greatest quantity about seven hrs. ($\frac{1}{2}$ —12) after a meal. Bile promotes digestion (1) by acting very slightly upon all the substances, more especially the respiratory matter; (2) by neutralizing the acidity of the stomachic chyme; (3) by aiding the separation of the chyle proper from the chyme; (4) by aiding the absorption of fat, lubricating the villi, and stimulating their action; (5) by stimulating the peristaltic action of the intestines. The greater part of the bile is reabsorbed, not, however, appearing in the blood as such—the rest (excretin, stercorin, &c.) being excreted with the fæces. (B) Bile and gastric juice are also antiseptic, preventing the natural decomposition of the food. (C) The liver possibly aids in the assimilation of newly-formed substances. (D) The veins of the intestinal canal, like all other veins, being possessed of very little selective power, absorb almost any diffusible substance, and the liver may serve to purify this from poisonous matters by arresting them and secreting the bile, which is formed from

this blood. (E) A great, but ill-understood function of the liver is the formation of an amyloid substance termed glycogen ($C^6 H^{10} O^6$) which (probably by contact with nitrogenous ferments found in the liver) becomes converted into saccharine glucose (or glycose), sometimes appearing as glucose in the blood of the hepatic vein, and the vena cava, and in slightly less proportion in the other parts of the body being decomposed in the muscles (probably, and also the lungs). It is very probable that glycogen is usually an intermediate stage in the formation of fat. Whether glucose normally appears in the liver during life is not determined: glycogen does appear there. The hepatic cells are thus both glycogen and bile formers: (some think the former only!) Non-nitrogenous food greatly augments the size of the liver by increasing the amyloid and fatty substances, the exact derivation of which is uncertain. Glycogen is also formed from nitrogenous material,—some albuminous substances splitting up in the liver into urea, protein, bile-elements, and glycogen. (F) In the embryo, and possibly, but very improbably, in the adult, the liver is a source of colourless blood-corpuscles.

51. The Pancreas (or 'sweet-bread') is a secretive gland 7 by 3 by $1\frac{1}{2}$ in., and weighing about 3 oz., situated behind the stomach, its tail touching the spleen. It is a compound racemose vesicular gland, supported by peritoneum, and having an external fibrous coat, which sends down septa dividing the parenchyma into lobes and lobules. Its minute structure resembles that of the salivary glands. Its secretion is conveyed by the pancreatic duct, or canal of Wirsung, to the duodenum which it enters, together with the choledoch. Its secretion is the pancreatic juice, an alkaline fluid, which somewhat resembles saliva, but contains no sulphocyanide of potassium, and is, moreover, a very powerful digestive fluid. Its chief active principle is pancreatine. It acts upon all kinds of food, but especially fat, converting the latter into an emulsion; its action upon albuminoids is very slight. About 7 oz. are secreted daily, sp. g. 1.010, and containing about .900 water.

CHAPTER III.

CIRCULATION.

52. THE great nutritive fluid of the body in general is the blood, which is conveyed to all parts by the circulatory organs, and is always contained in its own special vessels. The average amount of blood (including free lymph) contained in the body is about 14 lbs., or rather less; estimates range from 5—28; experiments from 10 to 26 +, (26 having been once lost by hæmorrhage); it varies much in different persons, and in the same individual, according to circumstances. Blood is an alkaline, albuminose fluid; sp. g. 1·055—1·060. It consists of a clear, colourless fluid portion—the serum, liquor sanguinis, or blood-plasma—in which float numerous moist cells or corpuscles (mostly red ones, but also a few white), and which compose about one-half (one-third?) of the volume of the blood. One thousand parts of blood consist of 795 (760—830) water; 205 solids (240 in healthy adults?), being cells (-water) 115 (130? 110—152), albumen 63 (40?), fibrin 3 ($1\frac{1}{2}$ — $3\frac{1}{2}$), fat 2, extractive matters and salts 22. The relative amount of various solids depends greatly upon the tests used. Red corpuscles consist of 690 water, 282 ‘globulin’ (consisting of paraglobulin, &c.), 16 hæmatin, &c.; sp. g. 1·088. Serum consists of 900 water, 79 albumen, 4 fibrin, &c.; sp. g. 1·027—1·028 (1·033). Blood in woman is poorer in corpuscles, but has richer serum (more albumen, &c.) than in man.

53. The temperature of the blood varies from about 100°—102° F. That coming from the liver and kidneys is the warmest, that from the skin coldest: the blood is slightly cooled (by evaporation) in passing through the lungs. But the temperature differs from the specific heat, or capacity

for producing heat, which is in the following proportions ; arterial blood, 103 ; venous blood, 89 ; muscle, 74 ; fat, 40.

54. The amount of gases in the blood is equal to about 48·2 per cent. of the total volume of the blood, when liberated ; of this 45·88 is free—that is, mechanically combined ; the rest loosely combined, its quantity depending partly on the test employed. The chemical formula of blood is :

	C	H	N	O
Arterial	50·2	6·6	16·2	26·3
Venous	55·7	6·4	16·2	12·7

The solid residue of blood is (in the ox) :

C	H	N	O	Ashes.
52·8	7·5	15	21·3	4·2

The formula of free and nearly free gases is :

	Carbonic Acid, Free.	Combined.	O	N
Arterial . . .	374·6	13·	203	16
Venous . . .	415·5	34·6	105	15

Thus venous blood contains less oxygen, but more carbonic acid (both free and combined).

55. Blood when drawn off coagulates, forming (1) a clot in the bottom of the vessel ; this clot, or crassamentum is dark-red, and consists of a whitish fibrous network of coagulated fibrin, which holds in its meshes the blood corpuscles,—the red ones displaying a tendency to form columns ; (2) a clear, yellowish liquid portion above, the serum. The weight of the corpuscles causes the clot to sink ; sometimes, as when the corpuscles sink rapidly, the upper part of the clot is whitish, consisting of fibrin devoid of corpuscles, and is termed the buffy coat. The clot, after a time, dissolves.

<i>Fluid Blood.</i>		<i>Coagulated Blood.</i>
Liquor sanguinis	{ Serum	Serum.
	{ Fibrin	
Corpuscles . .	Corpuscles }	Clot.

Fibrin probably does *not* exist as such during life, and its probable origin is the admixture of the fibrinous element of the serum, termed fibrinogen, with a small quantity of fibrinoplastin, or paraglobulin, which exudes from the

corpuscles; these two elements unite and coagulate, forming fibrin. Previously it was thought that fibrin was probably due to the circulation of the blood among the tissues, or that it subserved the formation of the tissues, being a more highly-developed kind of albumen.

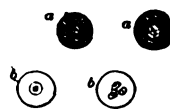
56. The red blood-corpuscles, cells, or globules are, in man, small biconcave discs, diam. $\frac{1}{8000}$ (varies from $\frac{1}{8800}$ — $\frac{1}{4000}$), thickness $\frac{1}{12400}$. In fœtus, diam. $\frac{1}{8800}$. They are devoid of nuclei, and of a proper cell-wall. They consist of two structureless parts—(1) a colourless jelly-like

Fig. 97.



- 1 1 red corpuscles.
- 2 seen edgewise.
- 3 gathered into rouleaux.
- 4 in cross section.

Fig. 98.

*White blood corpuscles.*

- a a as usually seen.
- b b treated with acetic acid.

stroma or frame, through which is diffused (2) a more fluid, coloured portion: the central part is, perhaps, more watery. There are about 66,000,000,000 to the cubic inch (I have seen calculations $\frac{1}{800}$ of this!), and it has been estimated that there are 20,000,000 births and deaths of these to each pulsation. Small globular red corpuscles are also frequently met with, $\frac{1}{8000}$ in. diam. upwards. The white or colourless corpuscles are much fewer in number than the red 1:1100

Fig. 99.

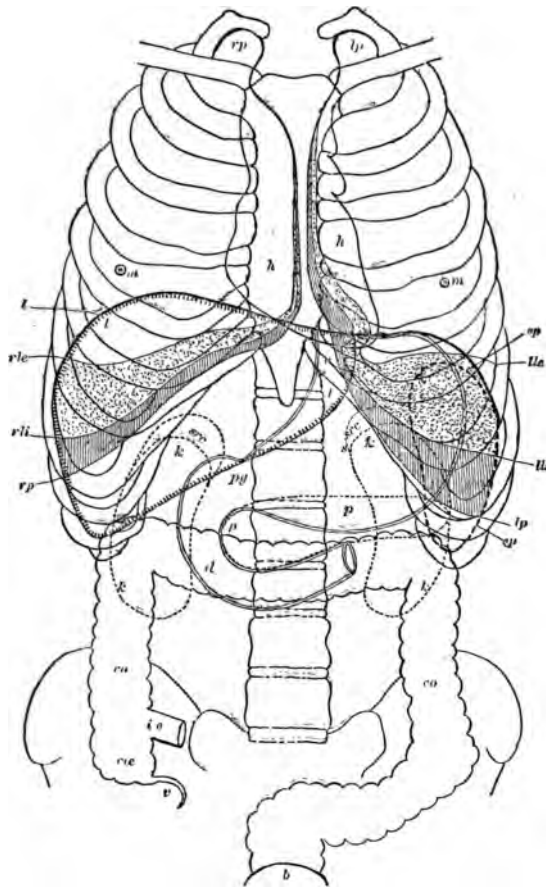
*White corpuscles (from newt.)*

Showing amoeboid changes undergone by two cells.

(1:300?), but their number varies, being much greater directly after meals, thus varying from 1:700 to 1:1800.

Each consists of a cell-wall, contents (either clear or granular), nucleus, and possibly nucleolus. Some consider the nucleus to be a post-mortem appearance, arising from the union of the granules. The white cells are usually roundish, but

FIG. 100.



Diagrammatic view of viscera.

m mammilla. h heart. rp limits of right pleura. rli of right lung after complete inspiration. rle of right lung after complete expiration. lp, lli, lle left pleura and lung after inspiration, and expiration. d diaphragm (thick line). l liver (line and dots). s stomach (double outline). c cardia. py pylorus. d duodenum. sp spleen (short strokes). k kidneys. src supra renal capsules. p pancreas. co colon. ca caecum. ic ileo-colic orifice. v vermiform appendage. b top of bladder.

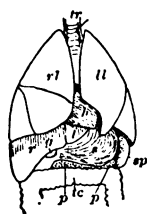
display spontaneous amœboid movements: size $\frac{1}{2600}$ diam.
The red corpuscles are probably developed from the nuclei

of the white, which are freed, and then become coloured. In the oviparous and the *embryos* of all vertebrates (man included), the red cells are derived from the entire white cells, which become coloured—some think in the adult also. Two facts, however, favour the view that they are derived from the nuclei; (1) sometimes the nuclei of the white cells are coloured; (2) in the camel tribe, in which the red-corpuscles are elliptical, the nuclei of the white ones are elliptical also. The white cells are developed from, or rather are lymph corpuscles, with which they are identical.

57. The circulatory organs consist of a central muscular vessel—the heart—which receives the blood, and propels it through the body, and of blood-vessels, which convey it; those which carry it to the various parts being termed arteries, those which bring it back, veins. Connecting the arteries and veins together peripherally is a network of minute canals, the blood capillaries. The heart is situated in the upper part of the thorax above the diaphragm.

58. The *thorax* is a rather conical cavity. Its floor is

FIG. 101.



Front view of the thoracic contents.

tr trachea. rl, ll right and left lungs.
h heart. r, l, right and left lobes of
liver. g gall-bladder. s stomach. sp
spleen. p, p pancreas. tc transverse
colon.

FIG. 102.



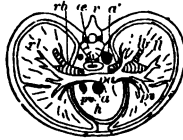
The thoracic contents seen from behind.

rl right lung. ll left lung. l liver. p pan-
creas. s spleen. k kidneys, with
supra-renal bodies. u ureters (upper
portion).

formed by the *diaphragm* or midriff, a veil-like partition, convex upwards attached to the sternum, lower ribs, and vertebral column. It is composed of striated muscular fibre—the fibres radiating, the centre being tendinous. The wall of the upper part of the cone is formed by the *ribs*, with the intercostal muscles joining them, the sternum, and the dorsal vertebræ. The thorax is lined by serous membrane—the two pleuræ, which are double sacs, the visceral layer of

each investing the lung of its side with a coat, the parietal layer lining the thorax, and forming a partition between the two lungs, the *mediastinum*, between the two layers of which

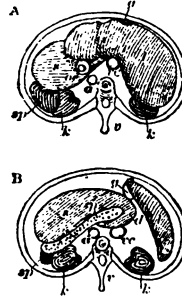
Fig. 103.



Section of upper part of thorax.

v vertebra. *rl, ll* right and left lungs. *h* heart. *pa* pulmonary artery and branches. *pv* a pulmonary vein. *rb, lb* right and left bronchi. *a* ascending, and *a'* descending aorta. *æ* oesophagus.

Fig. 104.

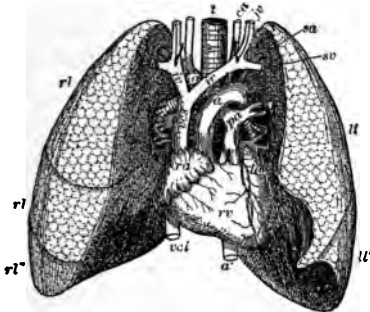


æ oesophagus. *s* stomach. *d* duodenum. *l* liver. *g* gall-bladder. *sp* spleen. *p* pancreas. *kk* kidneys. *a* aorta. *vc* vena cava inferior. *v* vertebra with spinal canal.

Two diagrammatic views of the thorax. A view beneath the diaphragm. B section through the base of the thorax.

lies the heart, enclosed in its proper serous sac—the *pericardium*—a reflection of which adheres to the outer wall of

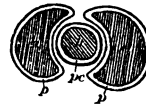
Fig. 105.



The heart and lungs from before.

rl, rl', rl'' the right lung. *ll, ll'* the left lung. *r* root of lung. *ra, rv* right auricle and ventricle of heart. *la, lv* left auricle and ventricle. *vci* vena cava inferior. *vcs* vena cava superior. *vi, vi* innominate veins. *jv* jugular veins. *sv* subclavian veins. *a* aorta. *a'* its descending portion. *ia* innominate artery. *ca* common carotid artery. *sa* subclavian artery. *pa* pulmonary artery.

Fig. 106.



Theoretical section of pleura and pericardium.

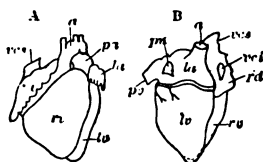
ll left lung
rl right lung.
pp two pleural sacs.
h heart.
pc pericardiac sac, in the mediastinal space.

the heart, and to the roots of the larger vessels which spring from it. The outer layer of pericardium is supported by

fibrous tissue. The outer layers of the pericardium and pleuræ are attached to the diaphragm.

59. The size of the heart is about $5 \times 3\frac{1}{2} \times 2\frac{1}{2}$ in., and it weighs about $10\frac{1}{2}$ oz. in man, 9 oz. in woman. The walls of the heart consist of modified striated muscular tissue, the fibres being devoid of sarcolemma, and apparently anastomosing with each other. The 'fibres' really consist of rows of apposed short, thick, striated cells, each containing a nucleus and nucleolus, having the cell-contents striated, and the ends of the cells often cleft into two or more thick branches, which meet those of other cells; thus forming the apparently anastomosing fibres. The serous inner lining of the heart is termed endocardium. The heart is suspended in its place by means of its vessels (the aorta, &c.) It lies rather to the front of the thorax, and partly behind the sternum—a line drawn through the centre of the thorax

FIG. 107.

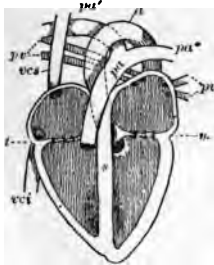


The heart.
 A anterior. B posterior face.
 ra right auricle. la left auricle. rv right ventricle.
 lv left ventricle. a aorta. pa pulmonary artery.
 pv, pv pulmonary veins. vcs vena cava superior.
 vci vena cava inferior.

antero-posteriorly would bisect the heart into two unequal portions, the greater being to the left side. It swings backwards and forwards rather diagonally, its apex striking between the fifth and sixth left ribs, where the 'impulse' may be felt externally. This movement is due to the spiral arrangement of the fibres, which are arranged in three complex layers—some reckon them as seven. The heart also twists a little transversely from left to right, and its upper part descends slightly behind. The heart is a double organ, consisting of a right and left half, completely separated from each other by the septum. The right half receives the venous blood coming from the body generally, and sends it to the lungs to be arterialized; the left half receiving the arterialized blood from the lungs, and sending it about the body. We thus see that the *pulmonary arteries* contain *venous*, and the *pulmonary veins* *arterial* blood: (the pulmonary veins possess no valves). The circulation in the body is

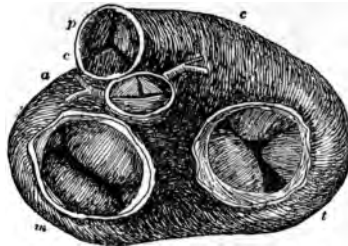
termed the greater, that in the lungs the lesser or pulmonary circulation. The heart consists of four cavities of about the same capacity, each probably capable during life of containing about 3—3½ oz. ($1\frac{1}{2}$ — $6\frac{1}{2}$). (1) The right auricle into which pour, each by its own opening, the vena cava inferior, which brings the venous blood from the head and arms, and the vena cava superior which brings it back from the rest of the body; this latter has, at its entrance, a rudimentary valve—the Eustachian. Below the right auricle is (2) the right ventricle: a valve, the tricuspid, guards the auriculo-ventricular opening connecting the two chambers. The ventricle has another opening guarded by a valve of three semilunar folds, and around it a fibrous ring, the

FIG. 108.

*Theoretical section of heart.*

ra, rv right auricle and ventricle. *la, lv* left auricle and ventricle. *s* septum. *t* tricuspid valve. *m* mitral valve. *vcs* vena cava superior. *vci* vena cava inferior. *pa* pulmonary aorta. *pa'*, *pa'* its right and left branches. *a* aorta. *pv, pv* the four pulmonary veins.

FIG. 109.

*Cross section of the heart seen from above.*

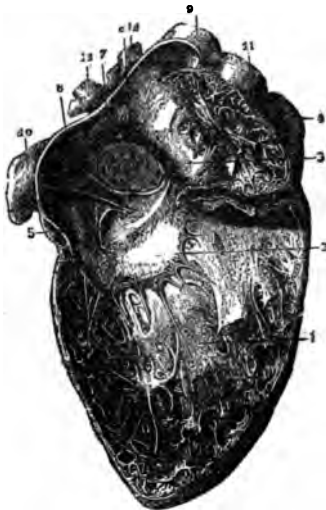
p pulmonary valves.
a aortic valve.
m mitral valve.
t tricuspid valve.

c, c coronary arteries, seen on either side of the aortic valve.

zona annularis; this is the commencement of the pulmonary artery, which soon bifurcates, sending a branch to each lung. (3) The left auricle has four openings in its upper part for the entrance of the four pulmonary veins, two from each lung, each of these immediately dividing into two branches, one of which goes to the upper lobe or lobes, one to the lower lobe; the two left veins sometimes enter together. (4) The left ventricle: the auriculo-ventricular opening, is guarded by the mitral valve consisting of two folds, and around it a zona annularis; there is also another opening which forms the commencement of the aorta, and which

is also defended by a semilunar three-folded valve. The auricles are connected in the embryo by an opening termed the foramen ovale, or hole of Botall, traces of which are seen in the adult in a depression caused by the walls being thinner; this is termed the fossa ovalis. Each of the auricles has thinner walls than either ventricle, and the cavities of the right side have thinner walls than those of the left: the walls

FIG. 110.



Vertical section of heart through right side (Sappey).

- 1 right ventricle. 2 tricuspid valve. 3 right auricle. 4 part of its wall. 5 embouchure of great coronary vein. 6 mouth of inferior vena cava. 7, 8 foramen ovale. 9 vena cava superior and embouchure. 10 inferior vena cava. 11 aorta. 12, 13 pulmonary veins.

FIG. 111.



Vertical section of heart through left side (Sappey).

- 1 left ventricle. 2 mitral valve. 3, 4 principal carnes columnæ of left and right sides. 5 mouth of aorta. 6 aorta. 7, 8, 9 aortic valves. 10 right ventricle. 11 septum. 12 pulmonary artery. 13, 14 its valves. 15 left auricle. 16, 17, 18 pulmonary veins. 19 section of coronary vein.

of the right v: left v: : 1: 2 (or 3); order of thickness thus is l.v., r.v., l.a., r.a. The auriculo-ventricular valves are fastened below by little tendinous cords, the chordæ tendineæ, which, by becoming stretched, prevent the valves flapping backwards, and so, upon ventricular contraction, preventing the regurgitation of the blood into the auricle. The inner walls of the ventricles are mostly covered by numerous fleshy pillars (columns, not pilasters), the carneæ columnæ, some

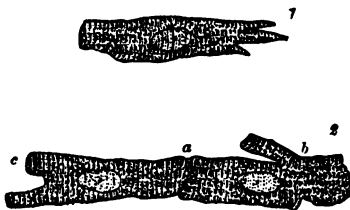
of which, the muscoli papillares, have the one end free, to which ends are attached the chordæ tendinæ; when the

FIG. 112.



*Muscular fibres of the heart magnified
(Kölliker).*

FIG. 113.



Three muscular fibre-cells from heart.

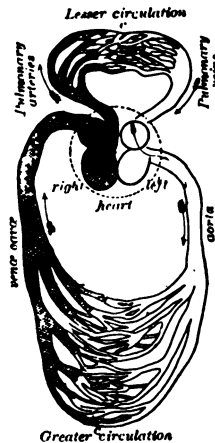
walls contract the muscoli papillares also contract, keeping the valves tight.

60. The action of the heart is as follows:—the right auricle containing venous blood contracts, driving it into the right ventricle; then the ventricle contracts, and the tricuspid valve preventing the return of the blood, this fluid passes into the pulmonary artery, and into the lungs; in a similar way, the left auricle having received the blood from the lungs, contracts, driving it into the left ventricle, which in its turn contracts, driving it into the aorta, and so over the whole body,—its return into the auricle being prevented by the mitral valve. The blood upon the contraction of the auricle is not driven into the veins, probably because it finds it easier to pass into the empty and extensible ventricle than into the full veins. The blood in the efferent vessels cannot return into the ventricles upon their contraction, because of the semilunar valves. All the valves of the right side close imperfectly, allowing some reflux. It will be seen that the right half of the heart contains venous, and the left arterial blood. The auricles contract simultaneously, then the ventricles also simultaneously; then there is a period of rest, during which both the auricles and ventricles slowly fill. The state of contraction is termed systole, that of dilatation, diastole. Relative time, aur: systole 1, vent: systole 4 (or 2), diastole of heart, 6 (2 or 3). Whether the expansion of the cavities

is partly due to muscular force, or solely to the filling with blood, is not determined—probably the latter. The heart thus acts as a kind of force-pump, the *available* force of each beat being about 4·6 lbs., being 6 lbs. ($3\frac{1}{2}$?) on the square inch, thus possessing an actual force of about 45 lbs. (51 ?) for the left ventricle only; the right ventricle has about one-third the strength of the left. The cavities normally empty themselves pretty completely, each time sending out about 3 oz. (1·5—6·3) at each beat.

61. The junction between the arteries and the veins is

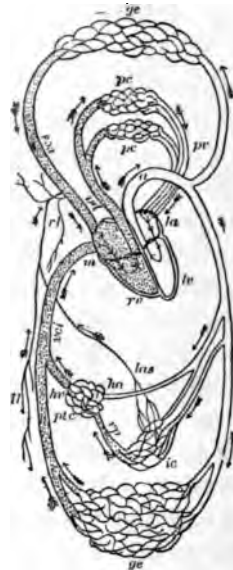
FIG. 114.



Theoretical diagram of circulation in mammals.

(The arrows indicate the direction of the current. The arterial blood is left white, the venous blood is shaded.)
cc capillaries.

FIG. 115.



Plan of adult circulation.

(The arrows indicate the direction of the currents. The shading indicates the degree of impurity of the blood.)

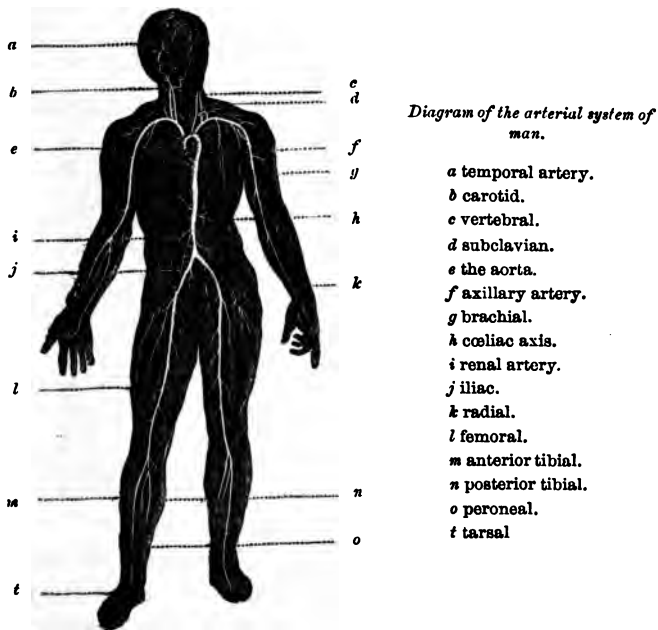
gc, gc' greater circulation in upper and lower parts. pc, pc lesser circulation in the two lungs. ic circulation of intestines, &c. pte portal circulation. lac lacteals. ll lymphatics of left side. rl lymphatics of right side. vcs vena cava superior. vci vena cava inferior. ra right auricle. rv right ventricle. pa pulmonary artery. pv pulmonary veins. la left auricle. lv left ventricle. a aorta. ha hepatic artery. vp vena portæ. hv hepatic vein.

formed by a minute network of capillaries. The aorta, conveying all the arterial blood, sends off branches which sub-

divide after the manner of a tree into smaller arteries and arterioles, the ultimate twigs ending in the capillaries; the arterial blood flows to the capillaries. The veins form two similar trees, the twigs of which end in the capillaries, but the blood in the veins flows towards the heart. All parts of the body are supplied with arterial blood. Four exceptions to the general plan are to be noticed in the circulatory system. (1) The pulmonary circulation. (2) The portal circulation: both already described. (3) The heart supply: the aorta at its commencement sends off two twigs, the coronary arteries; these supply the substance of the heart with blood, which returns by the coronary vein directly into the right auricle. (4) Renal circulation. In the kidneys, the arteries in the Malpighian corpuscles form a kind of network, again reuniting into small arteries to supply the true capillaries. An arterial network is termed a 'rete mirabile:' that in the kidneys is the only specimen in the human body.

62. The aorta, besides smaller branches, sends off firstly

FIG. 116.



a right innominate artery, which soon divides into a common carotid, and a subclavian artery, then the left common carotid and subclavian which come off separately: the two common carotids supply the head. Each of them subdivides into an

FIG. 117.



The main arteries of the upper extremities.

- 1 bend of the aorta.
- 2 arteria innominata (right side).
- 3, 3 subclavian arteries.
- 4, 4 common carotids.
- 4' internal, and 4'', 4''' external carotids.

FIG. 118.

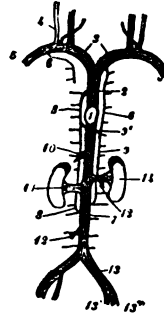
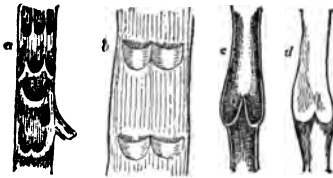


Diagram of the principal veins.

- 1 right auricle of heart. 2 vena cava superior. 3 vena innominata. 4 the three jugular veins. 5 subclavian vein. 6 superior intercostal veins. 7 vena cava inferior. 8, 8 vena azygos major. 9 vena azygos minor passing at 9' into the major. 10 root of hepatic vein. 11 renal veins. 12, 12' spermatic veins. 12' the left one coming from the left renal vein. 13 common iliac veins dividing into 13' internal and 13'' external iliac veins. 14 kidney.

internal and an external carotid; the external, which is at first the deeper seated, passes out and terminates as the temporal artery: the subclavian arteries supply the upper

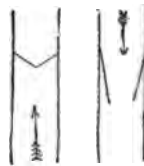
FIG. 119.



Vein valvules.

- a large vein.
- b small vein laid open.
- c section, and
- d external appearance of distended vein.

FIG. 120.



Plan illustrating the action of venous valves. The arrows indicate the direction of the blood current.

limbs. The aorta, after forming an arch, runs downwards, bifurcating below into the two common iliac arteries which supply the lower limbs. The two venæ innominatæ which

conjoin to form the vena cava superior are *each* formed by the junction of the three jugular veins coming from the head, and the subclavian vein from the arm; the vena cava inferior is formed (chiefly) by the junction of the two common iliac veins. The arteries rarely anastomose with each other (e.g. in the penis); the veins likewise anastomose but rarely, though more frequently than the arteries; usually do so at joints. The veins are more numerous than the arteries, and in the limbs are, for the most part, more superficial.

63. The capillaries are very small, varying from $\frac{1}{800}$ — $\frac{1}{2500}$ in different parts, usually about $\frac{1}{2500}$, which admits of

FIG. 121.



Capillaries of adipose tissue (Kölliker).

A capillary network. .

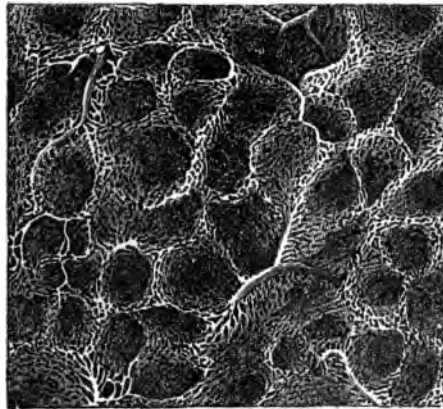
a artery.

b vein.

B Three fat cells with capillaries, more highly magnified.

a single file of corpuscles. The sectional area of all the capillaries is about 400 (or more) times greater than that of

FIG. 122.



Capillary network of lung. (Human. Kölliker, ♀).

(The hollows are the air-vesicles: a few arteries are seen).

the aorta. Their theoretical length (from artery to vein) is about the $\frac{1}{30}$ of an inch. The size and shape of the meshes

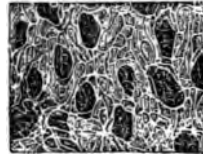
vary, forming very many and beautiful patterns. The meshes may be (1) circular, (2) oblong, or (3) coiled, with numerous

FIG. 123.



Blood-capillaries of gall-bladder (Kölliker).

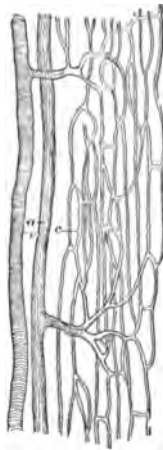
FIG. 124.



Capillaries of mucous membrane (intestine).

and various modifications, e. g. stomach, circular and oblong. The capillaries are very small, and have very small meshes in the lungs—the opposite in the muscles. The capillaries

FIG. 125.



Oblong-meshed capillaries of striated muscular fibre.

a artery. v vein. c capillaries.

FIG. 126.



Capillaries of the finger.

FIG. 127.

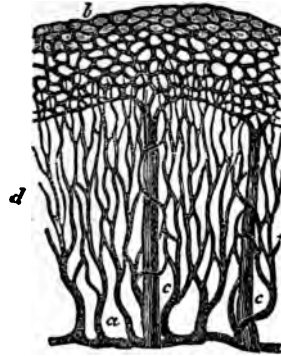


Capillary plexus from a fungiform papilla (After Berres).

consist of (1) an endothelium with regular oblong nuclei, and (2) a basement membrane, formed by connective tissue, and occasionally having its nuclei visible; sometimes these two layers are separate, and between them a lymph sinus,

e. g. in the brain. The capillaries are formed originally by an epithelial cell, sprouting out and meeting with another

FIG. 129.



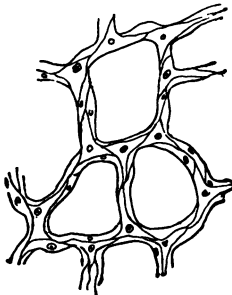
Capillaries of the stomach.
a, a arteries. b capillary network around mouths of glands. c, c veins. d capillary network between the glands.

FIG. 128.



Capillaries from retina. a a small artery.

FIG. 130.



Capillary vessels. (Cat.)

FIG. 131.

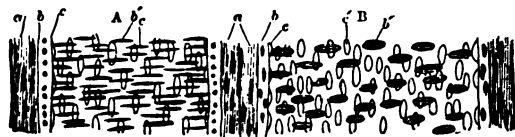


Development of capillary tubes.
1 masses of germinal matter hiding the nuclei.
2 a cell uniting two tubes.
3 another branched cell more hollowed out.

capillary, and becoming hollowed—not from coalesced fusi-form cells (the septa becoming absorbed).

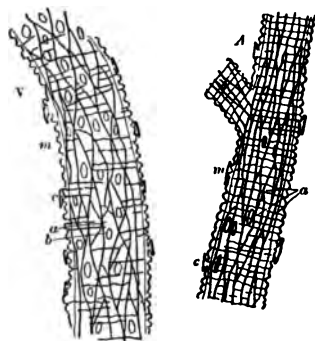
64. The small arteries are composed of (1) an inner coat of squamous epithelium, (2) a middle coat of non-striated fibre cells arranged circularly, (3) an outer coat of dense felted areolar tissue. As the arteries become larger, elastic tissue becomes mixed with the middle coat, becoming thicker and thicker, whilst the muscular fibres diminish. The veins are similarly composed, but have much thinner and less elastic walls than the arteries, so that when empty they

FIG. 132.



Small portions of A a small artery. B a small vein (highly magnified).
 a connective-tissue coat. b circular muscular fibre coat, cells appear round in section.
 c epithelial lining. b' nuclei of longitudinal fibres. c' nuclei of epithelium.

FIG. 133.



Histology of smaller blood-vessels. (After Quain.)

A artery. V vein. a, a epithelial cells (nucleated). m muscular fibre-cells (transverse), forming a layer in artery. c, c' connective-tissue corpuscles (scattered).

collapse. The structure of the largest arteries is (A, 1) epithelium, or *endothelium*, as it is often called in the blood-vessels and lymphatics, nuclei generally visible; (2) sometimes present either as striated or homogeneous tissue, containing nucleated connective-tissue cells, and sometimes mixed with elastic tissue; (3) perforated elastic and longitudinal non-striated fibres (one or both); (B, 1) circular non-striated cells; (2) white and yellow fibre; (C, 1) elastic (2) connective-tissue. In the larger veins, (A, 1) epithelium, (2) nucleated striated tissue, (3) elastic (rarely fenestrated); (B, 1) scanty non-striated fibres, (2) connective tissue and longitudinal elastic alternating with each other: B is absent in the hepatic, and some other veins; (C, 1) non-striated tissue rarely, (2) elastic and connective tissue.

65. The beating of the heart gives rise to the *pulse*, caused by a distending wave passing along the arteries, one to each beat. When examined by the sphygmograph this wave

sometimes appears to be triple. (1) 'Percussion' wave, almost simultaneous with the ventricular contraction, gives a sudden high jerk upwards. It travels 28·5 ft. per second, reaching the radial artery at the wrist in $\frac{1}{4}$ ". (2) 'Tidal,' or peridicrotic wave (one or more), probably artificial (due to oscillations following the sudden and too extensive jerk of delicate springs). The (diminished) percussion wave is, therefore, the real tidal wave of distension; its amplitude, *cæteris paribus*, varies inversely with the arterial tension. (3) As the above wave falls, there is another slight jerk, caused by the closure of the aortic valves; when this jerk is too manifest the pulse is said to be dicrotous. As the blood passes down through the arteries, the current, owing to the elasticity of

FIG. 134.

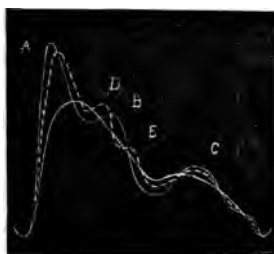


Diagram of pulse-waves. (After Galabin.)

The thick line represents, according to some, the true wave, the thin line the sphygmographic tracing, the dotted line the tracing of a sphygmograph with a secondary spring.

A percussion wave.

B tidal or first secondary wave.

C dicrotic or principal secondary wave.

D, E two small waves into which the tidal wave is broken by using a secondary spring.

their walls, gradually becomes continuous, the waves disappearing. Besides this, the sectional area of the smaller arteries and of the capillaries being so very much greater than that of the aorta, the pulse wave, when reduced to the $\frac{1}{100}$ or $\frac{1}{100}$ of its dimensions, could not be felt. The blood current travels in the arteries at the rate of $10\frac{1}{2}$ —12 in. per sec. in the larger, down to 2 in. in the smaller ones. The rate of circulation in the veins is slower than in the arteries, whilst in the capillaries it is only about $\frac{1}{80}$ in. per sec. ($1\frac{3}{4}$ in per min.), the rate depending upon sectional area. The pressure of the blood upon the walls diminishes as it progresses, in consequence of friction, being very small in veins. Arterial pressure is higher during the ventricular systole than diastole, higher during expiration than inspiration, lowest during the inter-respiratory pause. In the larger

arteries it is about 4·6 (or 6) lbs. per sq. in., in the larger veins 8 oz. It is everywhere low in the pulmonary circulation.

66. The great cause of the circulation is the force of the *heart*; this is aided practically by the resiliency of the elastic tissue in the walls of the arteries; the non-striated tissue serves to regulate the calibre of the arterial tube, and so the blood supply to any part,—a small *vaso-motor* nerve accompanying each artery for this purpose. Some think that the distension by blood at each pulsation causes the non-striated muscular fibre to contract, and thus aid in the propulsion of the blood; but this is uncertain. In the capillaries its flow is aided by a kind of capillary attraction, due to chemico-vital relations between the blood and the tissues, and tending to vary as the tissue-activity. The veins aid but little, or not at all, in the flow. The blood in the veins is prevented from flowing backwards by means of numerous valves along their course; these valves consist of semilunar folds, which form little pouches that open in the direction of the current. Muscular movements generally aid in the venous flow by pressing upon the veins, the valves of which hinder a backward current; these movements rather hinder during systole, but aid during diastole. Inspiration favours venous, slightly hinders arterial flow; expiration comparatively aids the arterial flow, slightly hinders the venous flow. Upon the whole, respiration favours circulation, especially in the veins. The heart makes two sounds, 'loobb-dup,' then there is a pause: probably the first is caused by the sudden closure of the auriculo-ventricular valves, and the second by that of the semilunar valves (of aorta and pulmonary artery). In deep expiration the blood in the veins is checked, causing a distension termed the venous pulse, which may be felt in the great vessels of the neck.

67. The rate of the pulse is about 72 or less (67—75) in the average adult man. It varies with age, sex, height (?), temperament, habits of life, posture, time of day, digestion, season of year, and atmospheric pressure. It is *quicker* in youth (in a newly-born infant, 138; in old age, 50—60; after 70 years again increasing slightly); women; short

persons; nervous temperament; town than country; ten beats faster standing than sitting, five sitting than lying down; in the morning; after meals (being quickest ordinarily two hours after breakfast); in spring and autumn; and under slight atmospheric pressure. Exertion and excitement also increase it—excessively for the time. It is faster during inspiration than expiration. Whatever the rate of the pulse, the duration of the ventricular systole always remains about the same, $\frac{1}{315}$ of a second. The ventricular systole seems to depend upon the intracardiac ganglia; the auricular systole, and so rate of pulse, upon the pneumogastrics.

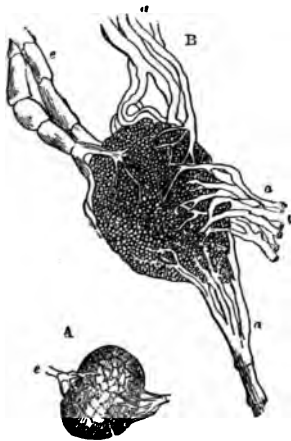
68. The white corpuscles move in the periphery of the current along the walls, dragging slowly along, the red corpuscles in the more central part moving from nine to seventeen times as fast. If this indicates that the more peripheral portions of the current move slower than the more central, calculations of the time for a complete circulation, when derived hence, are evidently inaccurate, since some parts would circulate nine times as fast as others. This would, however, account (1) for the fact that in bleeding, the blood becomes poorer and poorer in red corpuscles, and (2) for the rapidity with which some substances introduced into the blood make a complete circuit, some substances being known to travel thus much more rapidly than others. If the blood travelled at a uniform pace, a revolution would be made in about 75 beats, the above theory accounting for the appearance of some substances in about 27 beats.

69. The walls of the capillaries are extremely thin, allowing the serum to ooze through for the nourishment of the tissues, &c. The residue of the serum which oozes through, but is not made use of, as also a certain amount of effete matter derived from the tissues, is absorbed by the veins, and chiefly by the *lymphatics*, which form an *auxiliary set of veins*, which, commencing among the tissues, convey the enclosed *lymph* back to the veins, and so to the heart. The lymphatic ducts present a varicose appearance; at each knot there is a valve formed by two semilunar folds, allowing the lymph to flow only towards the heart; the canal expanding just above each valve gives the beaded appearance.

The lymphatics do not rapidly unite together to form larger branches as the veins do, and they increase in size but very slightly throughout. The larger lymphatic ducts are composed as follows:—(1) an inner coat of epithelial cells, flattened, nucleated, with wavy, indented, or serrated edges, supported by longitudinal elastic fibres; (2) a middle coat composed of connective-tissue, circular non-striated fibre and elastic fibre; (3) an outer coat of non-striated fibre and connective-tissue, with a little longitudinal elastic. The smallest ducts consist of only a squamous epithelium with wavy edges, supported generally by connective-tissue. Here and there upon their course is found a *lymphatic gland*. The afferent lymph ducts break up into several smaller branches previous to entering the gland. Both afferent and efferent ducts break up to form a network in the substance of the gland, which is also well supplied with blood-capillaries.

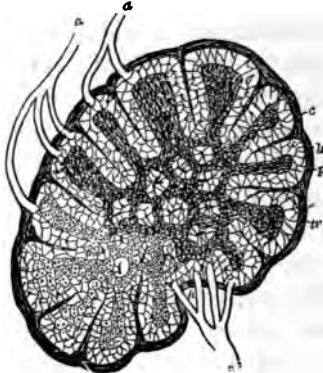
70. The lymph glands vary much in size, from that of a large shot to that of an almond: they are small, firm bodies,

FIG. 135.



Lymphatic gland.
A natural size. B magnified.
a, a afferent ducts. e efferent ducts.

FIG. 136.

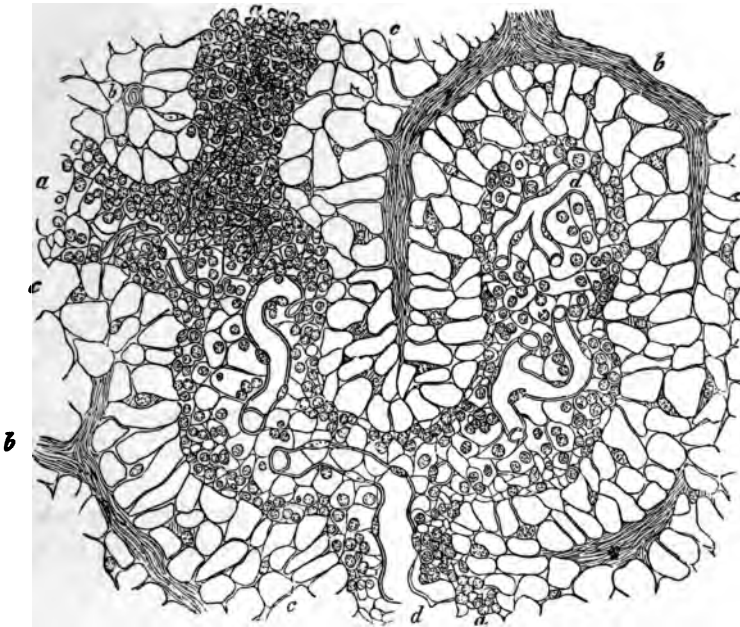


Section of a lymph gland.
a, a afferent lymphatics. e efferent lymphatics. h hilus. c fibrous capsule sending in tr trabeculae. p pulp. ls lymph sinus. The cells from the lymph-sinuses have been washed away, and in the left portion from the pulp also.

usually of a pinkish colour (white in mesentery, yellow in liver, black in lungs). Each has a capsule of areolar tissue, which sends out prolongations that dip into the substance of the

gland, dividing it by septa into alveolæ. Each gland is divisible into a cortical and a medullary portion; in the former the connective-tissue of the septa is laminated, and the alveoli form intercommunicating capsular spaces; in the latter it is scanty, and the alveoli are for the most part continuous. In the alveoli is a network of trabeculæ—of connective-tissue fibres, mixed with a few non-striated ones, and having frequent nuclei at the nodal points. Each

FIG. 137.



Section of medulla of lymphatic gland. (Ox. Von Recklinghausen.)
a, a central pulp. b, b trabeculæ. c, c lymph-sinus. d blood-vessel.

alveolus consists of a central 'pulp,' surrounded by a lymph sinus,—the trabeculæ in the pulp being much more dense, and holding the lymph corpuscles more firmly in the meshes. The medullary and cortical lymph sinuses, and also the pulp and lymph sinuses of each, are connected together. The afferent vessels open into the cortical—the efferent into the medullary lymph-sinuses. The external coat of the lymphatics becomes continuous with the gland-envelope. The

lymph sinuses are lined with an epithelium similar to that in the ducts. At certain places, e. g. various joints, a few afferent lymphatics break up into a network, which again unites to form a few efferent ducts, thus forming a rete mirabile, and this may be regarded as the simplest approach to a lymphatic gland, various intermediate forms being found.

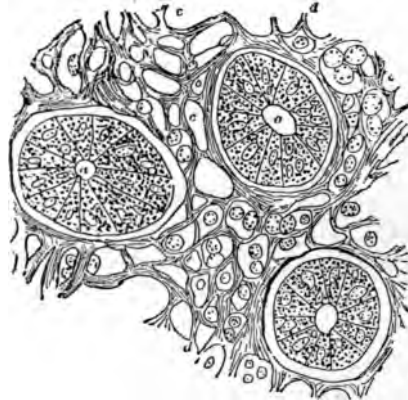
71. The smallest lymph radicles commence either in (1) the plexiform, or (2) the lacunar method. The lacunæ are

FIG. 139.

FIG. 138.



Lymph-radicles passing into capillary network.



Reticiform tissue. (Intestine of sheep. After Frey.)
a cavity of a Lieberkuhn's follicle. c, c lymphoid spaces, some of which contain cells, others are empty. d, d trabeculae.

lined with lymph epithelium cells. The plexiform somewhat resembles the interior of the glands, and consists of trabe-

FIG. 140.

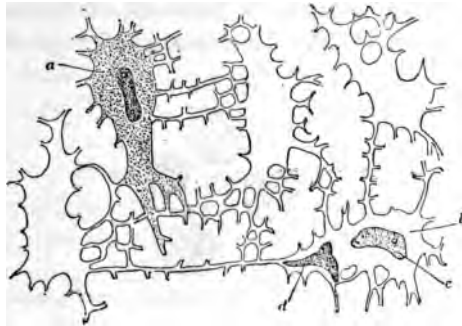


Serous membrane. Showing commencing lymphatics connected with cell-spaces. (The serous epithelium has been removed.)

culæ and lymph cells. The sub-mucous areolar tissue of the stomach and both intestines consists of plexiform lymphoid

tissue, also termed retiform, or adenoid tissue. The small ducts would seem sometimes to end in a lymphatic capillary or canalicular system, formed by a communicating network of connective-tissue cells in the ground substance, some of

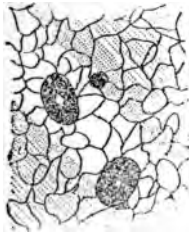
FIG. 141.



Lymph canalicular system (from cornea of frog): In *a* the cell-contents and nucleus are left; in *b*, the nucleus *c* and a migrating cell *d* are seen; the other lacunæ are empty.

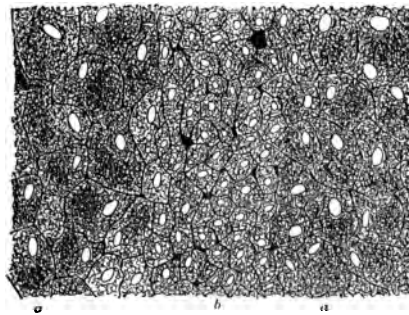
which are continuous with the epithelial cells of the walls of the regular channels, and so with the channels themselves—perhaps also by spaces between connective-tissue cells and bundles of fibres, and often by small lacunæ. The smaller

FIG. 142.



Serous epithelium. (Peritoneum of rabbit. After Klein.) Showing several *stomata*. Underneath, a lymph-channel lies between two tendon-bundles.

FIG. 143.



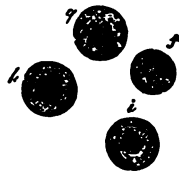
Serous epithelium. (Peritoneum of rabbit.) *a*, a larger cells. *b* smaller cells with a few *pseudo-stomata* (shown black) between them. The nuclei are left white.

lymph ducts sometimes open by stomata into the serous sacs, and the lymph ducts supply the fluid in them, thereby accounting for its identity with lymph. The stomata are of two kinds, (1) real stomata surrounded by a ring of a few

small granular cells ; (2) pseudostomata formed by a connective-tissue corpuscle process from below, opening between the epithelium cells into the cavity.

72. *Lymph* is a slightly yellowish, transparent, slightly alkaline fluid, very much resembling blood serum : it consists of 940 water, 43 albumen, a little fat, fibrin, salts and extractives : sp. g. 1.020. The lymph, before passing through

FIG. 144.



Lymph corpuscles. (Kölliker.) *g, h, i* various appearances.

the glands, is structureless, but afterwards (is coagulable, and) contains lymph-corpuscles, which are identical with the white blood-corpuscles, and which are derived from the glands.

73. The lymphatic ducts of the mesentery are called *lacteals*, or chyloferous vessels,—the glands, mesenteric glands. They bring the absorbed chyle from the intestines, the greater intestine being also supplied with lacteals, but

FIG. 145.



Lymphatics of gastric mucous membrane.
The tubules are faintly traced.

FIG. 146.

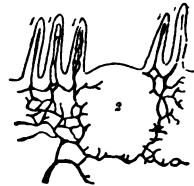


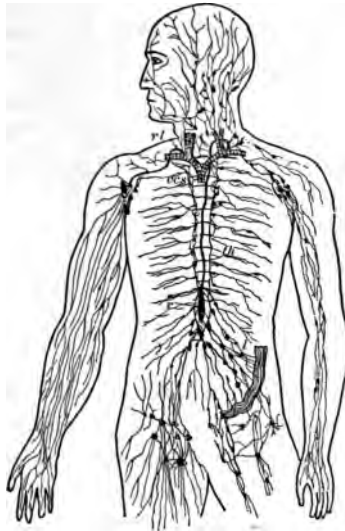
Diagram of lacteals in the mucous membrane of the lesser intestine.
1, 1 villi. 2 a Peyer's capsule.

no villi. The lymph contained in the lacteals assumes a whitish milky appearance after meals, and then consists of the absorbed intestinal chyme, plus a little lymph, thus constituting true chyle. *Chyle* resembles lymph, but is richer, and contains, besides the chyle corpuscles (identical

with the lymph corpuscles), nuclei and numerous molecules of fatty matter. Some of the chyle cells very possibly develop *de novo*, the granular molecu^l_æ uniting to form nuclei, which become cells; thus some of the cells are only about $\frac{1}{7000}$ in. diam., and devoid of any well-defined envelope. Chyle consists of 905 water, 71 albumen, &c.; compared with lymph it contains more fat and extractives, less fibrin and salts: in the ass, 35 albumen, 36 fat: sp. g. 1.030. Chyle varies much in composition, being often thinner than this.

74. All the lacteals, and the lymphatics of the left side of the body pour into the thoracic duct, dilated at its (abdominal) commencement: the enlargement is termed the receptaculum chyli. The duct empties into the left subclavian

FIG. 147.



The lymphatic system.

l lacteals. *r* receptaculum chyli. *th* thoracic duct. *rl* right lymphatic duct. *ves* vena cava superior and its branches. The superficial lymphatics of the right arm and leg, the deep ones of the left side are shown.

vein, its entrance being protected by two valvular folds. The lymphatics of the right side pour into the right subclavian at its junction with the right jugular. The lymph at the top of the thoracic duct assumes a pinkish colour.

75. Most lymphoid cells appear to be granular, and only under certain circumstances nucleated, which has led some to think that the nucleus (or nuclei) are artificial; but it is more probable (if the nuclei are not merely hidden by the granules), that after the formation of the cells the nucleus may again split up into granules. The majority of cells arise in the glands, where they probably multiply fissiparously. Besides from the lymph and chyle corpuscles, the white blood corpuscles also originate in the spleen, and very possibly the other ductless glands (and from the detached epithelium cells of the blood-vessels? and in the liver?), and

FIG. 148.

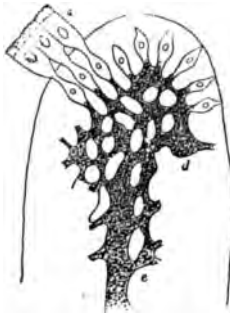


Diagram of lacteal origin in villi. (According to Funke.)
c columnar epithelial cells. *d* connective-tissue corpuscles forming a network.
e central lacteal.

FIG. 149.

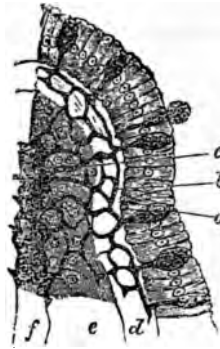


Diagram of lacteal origin in villi. (According to Letzerich.)
a goblet-cells. *b* plexus. *c, f* central lacteal. *d* connective-tissue. *e* the same with nuclei.

from marrow. The white corpuscles of the blood are supposed to exude through the walls, and then become amoeboid connective-tissue cells, from which are derived white fibre and the other connective-tissue cells, and from these again lymph-canalculi, and possibly lymph cells, thus forming a circuit. The cells of mucous glands are also identical with and perhaps derived from white or lymph corpuscles. There are about $6\frac{1}{2}$ lbs. of chyle, and 22 lbs. of lymph absorbed daily. The greater portion of the chyle being absorbed from the small intestine, the nutritious particles pass through the porous walls of the epithelial cells into them, or else into certain globular or goblet cells, which are of rather larger

size, devoid of an outer free wall, and with only a portion of the cell contents; they are found scattered among the other epithelial cells, and are possibly only worn-out cells. Beneath the epithelium are numerous connective-tissue cells, and the lymph, after being absorbed, either enters an intercellular canalicular network, or a cellular one, and thence into the central lacteal ($\frac{1}{1000}$ diam.): these lacteals break up into a network of smaller lacteals in the sub-mucous tissue.

76. Crystalloids being readily diffusible, and colloids not, the lymphatics are, perhaps, more particularly intended for the absorption of the colloids, and thus have thinner walls than the veins, which can absorb crystalloids. The veins have little or no selective power, the lymphatics some, the lacteals of the intestines still more, absorbing little except chyle. The absorbent (lymphatic and lacteal) glands have a slight alterative power, more completely organizing the fluid passing through them, and rendering it more similar to the blood; the waste matter of the lymph being, when poured into the blood, secreted along with the useless portions of that fluid; the useful portions being again organized and refitted for service. But, besides the lymphatic system, all the tissues have a selective and assimilative power, each drawing out of the blood what is suitable to it, abstracting similar substances, and then organizing them in a peculiar way; the rest, as well as the effete matter, being absorbed by the great sewerage system—the lymphatics. The blood itself has probably a certain amount of assimilative power. Between the blood and the tissues an osmosis is always going on,—chiefly of oxygen and carbonic acid,—the blood being to the tissues something like what the lungs are to the blood.

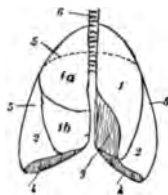
CHAPTER IV.

BLOOD-REGULATION.

77. **THERE** are certain organs set apart for keeping the blood pure by the excretion of useless and injurious substances, and by the absorption of useful ones. Such organs are the lungs and kidneys; these and the skin are collaborators. The lungs secrete and absorb; the kidneys secrete only: the skin chiefly secretes. The skin absorbs oxygen, and gives off carbonic acid (1 oz.) and a fraction of urea, besides water (33 oz.); but the amount of gases which passes by the skin is relatively unimportant as compared with what passes by the lungs.

78. The two lungs are situated in the upper part of the thorax, each invested in its pleura as in a double bag, one lung on either side of the heart. The left lung is divided into two

FIG. 150.



Lungs. Showing their division into lobes (seen from before).

1 upper lobe, divided into two in the right lung. 2 lower lobe, in left lung a space is hollowed out at 3 for the heart. 4 concave base of the lung. 5 great fissure. 6 its course on posterior surface, figured as though the lung were transparent. 6 trachea.

FIG. 151.



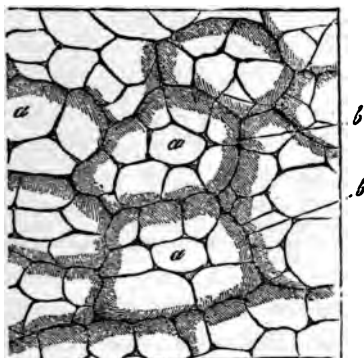
The lungs. Outer side.

A right lung. 1, 2, 3 its three lobes.
B left lung. 1', 2' its two lobes.

lobes, the right (which is the larger as 8:7) into three, (the middle lobe may be considered as the lower portion of the upper). The weight of both lungs is about 45 oz. (32—48) in man, the right being 24, the left 21 : in women both together

weigh 32 oz. In shape each lung is an irregular half-cone, apex upwards, the inner side flattened, the base concave. The bronchi and large vessels enter at the *root* about $\frac{2}{3}$ down and $\frac{2}{3}$ backwards. The left is the longer, but the right the larger. Each consists of an air-tree of bronchial tubes, the

FIG. 152.



Outer surface of lung. (Cov. Kölliker $\frac{2}{3}$)
a, a air vesicles. b, b margins of smallest lobules.

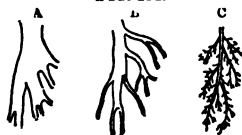
FIG. 153.



Lobules of human lung, separated.
Natural size.

smallest ones (about $\frac{1}{40}$ in. diam.) each ending in an alveolar or lobular passage which divides into several smaller sacculated ones with enlarged extremities, constituting an irregular pouch—infundibulum (one to each parenchymatous lobule), whose walls are honey-combed with shallow cup-shaped

FIG. 154.



Bronchia.

A division of primary into secondary, B of secondary into tertiary, and C of tertiary into ultimate bronchia.

FIG. 55.



Three ultimate lobules with bronchial ramifications seen in section, slightly magnified.

depressions termed alveoli, pulmonary vesicles, air-cells, or locules, diam. $\frac{1}{100}$ in. ($\frac{1}{70}$ — $\frac{1}{200}$). The more external alveoli are the larger. A dense network of projecting capillaries is distributed upon the walls of the air-cells, and the septa between the cells have but a single layer of capillaries

(developmentally two; these become interlocked), the capillaries winding from one surface to the other, so that in the septa the air often gets at both surfaces. The pulmonary arterioles usually run towards the top of the septa, the veins below. The capillaries have a diameter of $\frac{1}{3000}$ in.: meshes circular, and of about equal diameter ($\frac{1}{3000}$)

FIG. 156.



External view of infundibulum and alveoli.

FIG. 157.



Section of an infundibulum.
b terminal bronchial tube. l lobular passage. l' l' its branches. a, a air-cells.

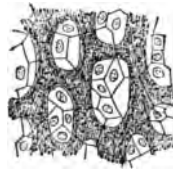
only. It is estimated that there are 1,800,000,000 air-cells in the lungs, thus exposing about 1800 square feet (1400—2642) to the atmosphere, and the capillaries of the lungs, if made continuous, would reach fully $\frac{1}{3}$ round the earth! A thin squamous epithelium lines the vesicles: the cells are of two kinds, large transparent ones and smaller nucleated

FIG. 158.



Lung-capillaries.
One alveolus and a portion of several others are shown. a, a pulmonary arterioles. w alveolar wall seen in section.

FIG. 159.



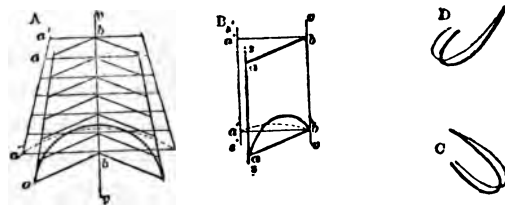
Pulmonary epithelium. (Cat.)
The subjacent capillaries are shaded.

(sometimes nucleolated) granular ones; the granular ones are found (often in groups of three or four) lying in the intercapillary spaces only. The trabecular tissue in the walls is composed of homogeneous connective-tissue, with numerous elastic fibres, and a few non-striated ones. The lobules of the lungs are held together by areolar tissue, like

in the glands. Several ultimate lobules (each enclosing an infundibulum) unite in groups to form the lobules, which are distinguishable on the surface of the lung, their outlines being marked by black pigment-cells, which are common in the lungs, especially those of coal-miners, &c.—are scanty in children. The lung tissue is supplied with *arterial* blood by small systemic arteries—the bronchial arteries—belonging to the greater circulation. The smaller arteries of the two systems communicate.

79. The movements of respiration are rather complicate; the diaphragm, intercostals, and the elastic tissue of the lungs being the chief agents. In ordinary inspiration, the external intercostals, which run obliquely downwards and forwards between the ribs, from the rib above to that below, contract, thereby raising the ribs outwards, (forwards, laterally, and [slightly] backwards), and upwards; the ribs sloping downwards during rest, thus become more horizontal; the sternum partakes a very little in the movement,—in women

FIG. 160.



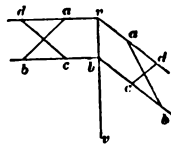
Action of the ribs and diaphragm in respiration.

A front view. B side view. C front view of the action of a single rib. D lateral view. *a b* direction of ribs before and *a' b'* after respiration. *e e* vertebral column. *s s' s'* sternum before and after respiration. The curved line is the diaphragm.

considerably so, but in some men not at all; the diaphragm also contracts, becoming more flattened, and pushing the abdominal viscera downwards: the diaphragm is the chief agent in ordinary inspiration, and its force is comparatively uniform; so that the cavity of the thorax by both sets of movements is increased in all directions; a few other muscles aid slightly,—some checking the upward elevation of the lowest ribs. In very active inspiration the pectoral respiration becomes very deep, the abdominal or diaphragmatic breathing remains stationary (the diaphragm, however, contracting),

and the elevation of the abdomen somewhat diminishes: other muscles also are then brought into play. The increase of the thoracic cavity causes the air to rush into the chest, thereby inflating the lungs, which glide freely in the thorax. In expiration, the above muscles cease their contraction, whereupon the stretched elastic tissue of the lungs reduces these organs to their natural size, at the same time forcing the air out of the chest. The internal intercostals which run downwards and backwards between the ribs are generally considered to aid in expiration; but it seems more probable that only their true costal portions do so, the intercartilaginous portions aiding inspiration. A few other muscles aid—more still in forced expiration. The elevation of the abdomen is least in forced inspiration, greatest in forced expira-

FIG. 161.



Theoretical action of the intercostal muscles.

a b direction of external intercostals before and *a' b'* after inspiration. *e d c' d'* internal intercostals. *v v v* vertebral column. *v d v d' v b' v b* ribs.

tion. During ordinary breathing in women the pectoral respiration comparatively predominates, in men and children the abdominal: man's breathing is sometimes termed inferior costal, because the sides of the chest make the most obvious movement,—that of women superior costal, because the front of the chest above the breasts moves most; the difference observed in women is a provision for times of gestation.

80. The amount of force used in respiration is as follows: 170 lbs. lifted (1 ft.) in ordinary, 450 in extraordinary inspiration; 1046 lbs. + the elasticity of the lungs being also resisted: the inspiratory muscles lift 2 oz. of mercury (1·5—7), the expiratory $2\frac{1}{2}$ oz. (2—10), varying according to the depth of respiration.

81. The adult man breathes about 18 times per min. (16—20): about 20 cub. in. of air are taken in each time, 16—33·6 cub. in. being the estimated averages, 7—92 cub. in. being the actual extremes: thus about 300 cub. ft. of

air are required every 24 hrs. There is always a certain amount of air in the lungs.

After a forced expiration,	110 cub. in. of residual air.
„ an ordinary expiration,	60 more of supplemental air.
„ an ordinary inspiration,	20 „ tidal air.
„ a forced inspiration,	145 „ complemental air.

Altogether after a forced inspiration, there are 335 cub. in., of which 225 are movable: the amount of movable air is called the measure of the *vital capacity*. Vital capacity varies, increasing with age between 15 and 35 years in the male sex; with weight, 8 cub. in. per 5 lbs. up to 11 stone; and

FIG. 162.

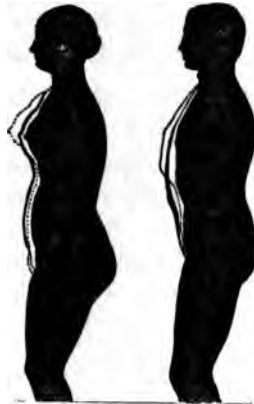


Diagram of respiration in both sexes.

The body after forced expiration is shown black: the continuous line indicates the outline in ordinary inspiration, the thickness of the line indicates the amount of displacement, the dotted line shows the limits of forced respiration.

with height, apart from weight: fat, consumption, general ill-health, and sedentary habits all diminish it: in warm climates and hot weather it is greater than in cold; but this is due rather to diminished respiration than to any actual increase of capacity, less blood going to the lungs. Women breathe more frequently than men (about 20 times per min.) In the new-born infant there are 44 inspirations per min. There is about 1 inspiration to every 4 pulsations ($4\frac{1}{2}$ —5). The time occupied is respectively inspiration 6, expiration 7 or 8, inter-respiratory pause 1. This post-expiratory pause only occurs in rather deep breathing—does not occur in

quick breathing—*perhaps* not in ordinary breathing during daytime, the latter part of expiration being, however, very slow : a post-inspiratory pause sometimes occurs. Exercise

FIG. 163.



Tracing of the normal respiratory movements during muscular repose. (Marey.)

Taken by Marey's pneumograph. Two waves are seen.

The down-strokes represent inspiration, the up-strokes expiration, the undulations at the apex are due to the cardiac beats, the apex represents Longet's 'pause.'

and excitement increase the depth and frequency of inspiration. Sighing, yawning, the hiccough, sobbing, crying, laughing, coughing, and sneezing are modifications of breathing. The expired air has always a temperature of about 95.5° — 97.41° F.

82. The lungs absorb oxygen, and give off carbonic acid and water.

	Pure air.	Respired air.
Oxygen . . .	20.61	15.83
Nitrogen . . .	77.95	77.95
Carbonic acid . . .	0.04	4.39
Aqueous vapour . . .	1.40	1.42

The nitrogen varies very slightly *either* way. The amount of water given off by the lungs is about 9 oz. per diem. The air, it will be seen, loses about 4.78 per cent. of oxygen, and gains 4.35 per cent. of carbonic acid; but it is to be remembered that however many times the same air be respired, it never loses above 10 per cent. of its oxygen, or gains above 10 per cent. of carbonic acid; hence the importance of pure air, good ventilation, &c. The respiratory activity varies much; is increased by exercise (up to seven times), cold, nitrogenous food, &c. During the night (12 hours) about 6000 grains of carbonic acid are given off: during a day (12 hours) of rest, 8000 grains,—of work 12,000 grains; that is, about 10 oz. of pure carbon during

a working day (24 hours); usually perhaps 9 oz. The more frequent the inspirations, the more the carbonic acid given off, though less at each inspiration. The oxygen absorbed chiefly goes to form the carbonic acid secreted by the lungs (and skin),—the rest to oxidize other substances—e. g. combining with hydrogen to form water, &c. According to some, about *twice* as much oxygen is absorbed during the night as during the day. Traces of other substances are also found in expired air. The air expired, if reduced to the same temperature as that inspired, would be less in volume as 99 (or 99·59) : 100.

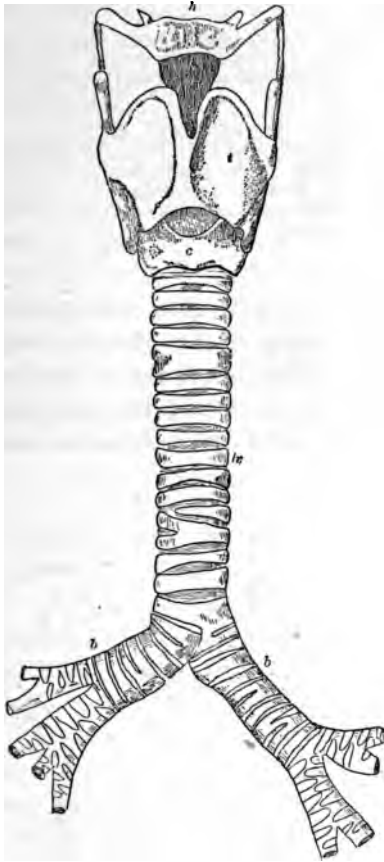
88. The lungs ordinarily contain about $\frac{1}{6}$ of the amount of blood in the body. Theoretically the air-current passes down chiefly by the centre of the tubes, and back chiefly by the peripheries. The air nowhere has free access to the blood, but always has to permeate two walls,—that of the air-sacs and that of the capillaries,—both, however, of extreme tenuity. During inspiration the pressure of the air upon the lungs becomes negative; during expiration it returns to an equal state (in forced expiration, coughing, &c., is positive). The pressure of the atmosphere depends upon the gases individually and not collectively. Two gases in contact with one another tend to become diffused into an uniform mixture. Oxygen is of slow diffusibility, and its absorption depends upon chemical affinity rather than upon pressure. The current of pure air introduced in inspiration does not reach farther than the upper bronchial tubes, so that the tidal mixes with the residual and supplemental air according to the law of gaseous diffusion mentioned; and thus in forced expiration the supplemental air is found to contain more carbonic acid than the tidal. When two substances of different density are separated by a porous membrane, both pass through, but in different proportions, the fluid, or gas, for which the membrane has most affinity passing in greatest abundance into the other: thus arterial blood has affinity for the tissues, and venous blood for the oxygen in the lungs; this aids capillary attraction and circulation. It also accounts in part for secretion (increased blood-pressure being another factor).

84. The venous blood, as it comes to the lungs through the pulmonary arteries, is of a dark purplish colour, whilst in the pulmonary veins and systemic arteries it is of a bright scarlet. This change is due to an alteration in the red corpuscles, which in the venous blood are more globular, more transparent, (perhaps have thinner walls), and transmit light more freely than those of arterial blood: oxygen flattens the red corpuscles, and sometimes seems to give them a tendency to flow parallel to each other. The red corpuscles are the great oxygen-carriers of the body. The change of colour *may* be due to the iron (in the hæmatin); in venous blood it is in the form of protocarbonate, then carbonic acid being given off, it becomes protoxide, then receiving oxygen, sesquioxide. Blood is not exactly of the same colour, quality, or heat in the different veins: more blood being sent to the (secretive) glands during their action than is requisite for their nourishment, the blood then coming from them is of a brighter red than usual: it also differs slightly in quality in the various veins according to the substances drawn off by secretion, &c., being usually also richer (containing more solid matters relatively) after passing through the glands. The blood in the renal vein is the purest in the body—the brightest red—and about the richest.

85. The air enters the pharynx by the two nasal passages properly, or else by the mouth; and this is to be observed in cold weather, for the air becomes warmed and moistened in its passage through the nares and pharynx ere its arrival at the delicate membrane of the larynx, &c. At the lower and front part of the pharynx is an opening which leads to the trachea, and thence to the lungs. This orifice opens immediately into a chamber, the *larynx*, in the walls of which are several cartilages united by membrane. (1) The Thyroid, which is the largest, forms the 'Adam's apple.' It lies in front of the larynx, and is deficient behind. It is attached above by membrane to the hyoid bone. (2) The cricoid, shaped like a signet ring, broadest behind. (3 and 4) The two small Arytenoid cartilages, both of a pyramidal shape, and attached by their bases to the cricoid. (5 and 6)

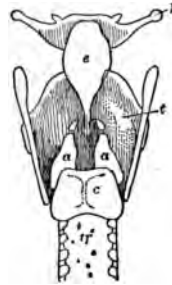
The two cartilages of Santorini, or cornicula laryngis, very minute, joined to the apices of the arytenoids. (7 and 8) The two cuneiform cartilages of Wrisberg, also very minute, in the membrane between the arytenoids and the epiglottis.

FIG. 164.



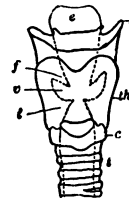
Larynx, trachea, and bronchi. Anterior aspect.
h hyoid bone. *t* thyroid cartilage. *c* cricoid cartilage. *tr* trachea. *b b* the two bronchi.

FIG. 165.



The larynx seen from behind.
h hyoid bone. *e* epiglottis. *t* thyroid cartilage. *a a* arytenoid cartilages with the cornicula. *c* cricoid cartilage. *tr* membranous posterior of trachea.

FIG. 166.

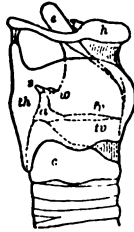


Larynx from before.
h hyoid bone. *e* epiglottis. *th* thyroid. *c* cricoid cartilage. *t* trachea. *f t* false and true vocal cords. *v* ventricle.

Like the arytenoids and Santorini's, these form a symmetrically disposed pair. (9) The epiglottis is leaf-shaped, the apex downwards; its upper half is free, but it is attached below by ligaments to the inner surface of the thyroid, and

more indirectly by membranous processes to the arytenoids, the hyoid bone, and the base of the tongue. The first four (1—4) are of true cartilage, and partly ossify in the male. The last five (5—9) are of yellow elastic or spongy cartilage, and do not ossify. The lower, or true vocal cords, are two

FIG. 167.



Larynx from the right side and rather before. (The larynx is supposed to be transparent.)

h hyoid bone. *e* epiglottis. *th* thyroid. *c* cricoid. *a* arytenoid. *s* Santorini's and *w* Wrisberg's cartilages. *fv* *tv* false and true vocal cords.

thin membranous folds of yellow elastic fibre and mucous membrane, which lie on either side of the glottis, being attached behind to the bases of the arytenoid and in front to the thyroid—the central opening is termed the *glottis*, or *rima glottidis*. The two upper or false vocal cords are

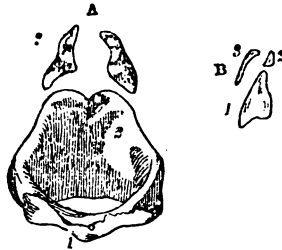
FIG. 168.



Thyroid cartilage (front view).

1 'Adam's apple.' 2 (right) ala or wing
3, 4 superior and inferior cornua.

FIG. 169.



Cricoid, arytenoid, and other cartilages.

A cricoid and arytenoid cartilages (front view). 1 front of cricoid. 2 interior of back of cricoid. 3 the two arytenoids.
B Anterior surface of lesser cartilages of right side. 1 arytenoid. 2 cartilage of Santorini. 3 cartilage of Wrisberg.

similarly attached a short distance above: they consist of mucous membrane only. Between the true and false vocal cords on either side is a hollow, prolonged into a slight saccule in front: these are the two *ventricula laryngis*.

86. The larynx opens below into the *trachea* or wind-pipe,

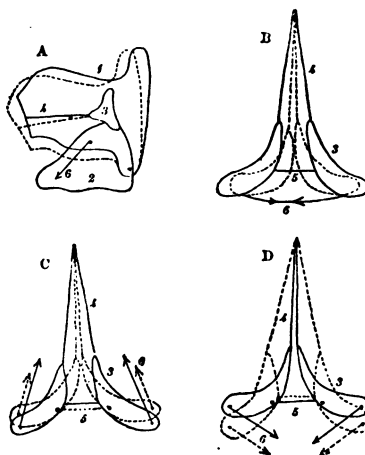
which is about 4 in. long, $\frac{3}{4}$ in. diam., and lies in front of the œsophagus. It has a ribbed surface, owing to a number of cartilaginous rings being embedded in it. There are 16 to 20 rings in men, less in women. These rings are sometimes forked, and all are imperfect behind. The trachea consists of (1) an outer fibrous layer, in which the cartilages are embedded; (2) a very few longitudinal, and some transverse smooth muscular fibres in back part of tube,—the latter serving to contract the trachea by approximating the ends of the cartilages; (3) sub-mucous areolar tissue, with longitudinal elastic; (4) mucous membrane—much lymphoid and elastic tissues with a stratified columnar epithelium, the outer or free layer ciliated and sending processes inwards. Small racemose mucous glands are found in its walls, as also in those of the larynx and bronchia. The trachea divides at its lower extremity into two *bronchi*, one of which goes to each lung, and there subdivides into secondary, tertiary, and terminal *bronchial tubes*. The bronchi enter upon the inner surface of the lungs, the right opposite the fourth, the left opposite the fifth dorsal vertebra. The right bronchus (1 in. long, 7 rings) has a greater diameter than the left ($1\frac{1}{4}$ in. long, 10 rings). Incomplete cartilaginous rings are seen in the larger tubes, gradually becoming more imperfect, and finally being absent in the smaller ones. The structure of the larger bronchia is similar to that of the trachea, the cartilages being imperfect behind, and the muscular fibres existing only behind. In the smaller bronchia the structure is very similar, but the imperfections are not always behind; the walls, of course, become thinner, and the muscular fibres form a complete circular layer. The ciliæ desist upon entering the air-vesicles, and the muscular fibres almost immediately afterwards.

87. Voice is produced by the vibration of the true vocal cords: when the cords are rendered tense by the action of certain muscles, breathing causes a state of rapid vibration to ensue, and this produces a sound. The state of the vocal cords is *chiefly* regulated by certain 'intrinsic' muscles, all of which, except the posterior, or transverse arytenoid, are arranged in pairs.

1. Crico-thyroid, stretches the cords, dilates the glottis.
2. Thyro-arytenoid, relaxes the cords, closes the glottis.
3. Crico-arytenoid posterior, dilates the glottis (especially the anterior part).
4. Crico-arytenoid lateral, closes the glottis (" ").
5. Transverse-arytenoid, closes the glottis.

1 and 2 are antagonistic, as also 3 and 4. The internal part of the thyro-arytenoid muscle renders the vocal cords tense as a whole, preventing the vibration of isolated parts. The shorter the vocal cords, or the more tense they are, the shriller the note produced: the former accounts partly for the difference of voice between the two sexes, the larynx

FIG. 170.



Action of the muscles of the larynx.

The dotted lines indicate the new position assumed by the vocal cords, &c., upon the contraction of the muscle.

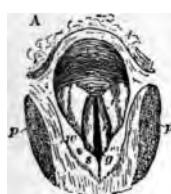
A action of the crico-thyroid. B posterior arytenoid. C lateral crico-arytenoid. D posterior crico-arytenoid.

1 thyroid. 2 cricoid and 3 arytenoid cartilages. 4 inferior vocal cords. 5 posterior border of the glottis. 6 the arrows indicate the direction of the muscular traction.

growing larger at the same time that it ossifies in the male; the latter chiefly for the difference of key produced by the same person. The greater the sound the stronger the current of air; and so, if unopposed, the more tense would be the vocal cords and the shriller the note, for a strong current tends to render them tense. The vocal cords in a state of rest are in man $\frac{7.2}{100}$ in. long, in woman $\frac{5.1}{100}$, when tense as possible $\frac{9.3}{100}$ and $\frac{6.3}{100}$ respectively. During vocali-

zation the anterior $\frac{2}{3}$ of the glottis (the vocal glottis) is always open, but the posterior $\frac{1}{3}$ (the respiratory glottis) sometimes closes: no sound whatever is produced by the respiratory glottis alone, nor any by the vocal glottis if

FIG. 171.



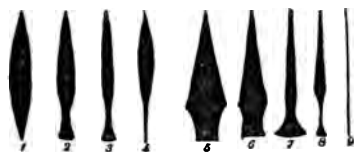
The larynx seen from above. Showing the glottis, &c.

A during utterance of a high-pitched note. B during deep inspiration.

p pharynx. w nodule corresponding to cartilage of Wrisberg. s that of Santorini. g glottis. t true vocal cords. f false vocal cords. b the bifurcation of the trachea and commencement of the two bronchi.

wider than $\frac{1}{10}$ in. The shriller the sound, the more frequent the vibrations of the cords, and the narrower the glottis; the higher also is the larynx drawn up, and various other modifications of the vocal tube above and below are pro-

FIG. 172.



1 deep sounds.

2 medium sounds.

3 shrill sounds.

4 falsetto notes.

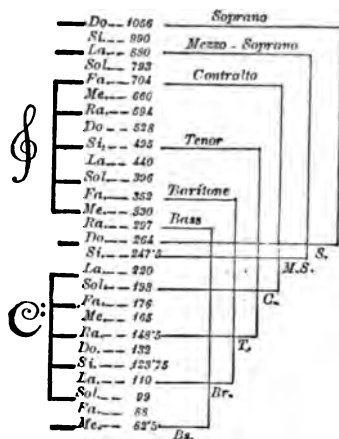
5, 6, 7, 8, 9 different shapes which the glottis may assume.

duced by the action of extrinsic muscles, chiefly affecting the length, area, and tensivity of the walls, so as to resonate or reciprocate the sound produced by the cords. The narrowing of the glottis also tends to render notes more shrill.

88. The usual compass of the human voice ranges between 82.5 and 1056 vibrations per sec. (44—1708 being the extremes) and in the same individual usually about 2 to 2½ octaves. Voices are divided into soprano or treble, mezzo-soprano, contralto or alto, tenor, barytone, and bass respectively, the first being the most shrill. The cause of the falsetto or head-notes in man is unknown. The opening of the glottis is rather wider in head-notes (for notes of the same pitch presumably). According to some, in true or chest notes both glottides are open, becoming narrower the shriller the note, especially at the point of division between the two, and the whole of the true vocal cords vibrate, whilst in the

false notes, the respiratory glottis closes, and the upper vocal cords are applied to the lower ones, so that the edges only of these vibrate; some think that the edges are stretched by the internal thyro-arytenoid fibres. Again,

FIG. 173.



The range of the various human voices. The numbers are the double vibration numbers.

some say that the respiratory glottis is always closed during vocalization. The falsetto notes are an octave higher than the natural ones, and so it requires double the number of vibrations to produce them.

89. The apparatus of the voice consists essentially of a reed-pipe,—the vocal cords forming the tongue, and a resonance-cavity,—the mouth and air passages above. Sounds are of two kinds; (1) musical, when the vibrations are synchronous, or all of equal periods of time; (2) noises, when the vibrations are of unequal times. Vowels are musical sounds, consonants are noises. Speech without voice is a whisper, and the sound, similar to that of consonants when not whispered, depends upon the air rushing against various parts of the resonating cavity, and causing them to vibrate. Each vowel has a natural pitch i (ē), being the highest, u (oo) the lowest. The larynx is raised more and more with the higher vowels. In producing the vowels, the size of the oral cavity, and of the oral orifice are also altered. The consonants

are produced by various more or less complete obstructions placed at different parts. Thus, the vowels are formed in the larynx, and have certain harmonics (different for the different vowels) reinforced by the additional tube, whilst the consonants are formed in the additional tube.

90. There are eight vowels—i, e, â, á, ă, o, u, and er (or ur vocal as in burn) ; (i=English ē, e=ā, â=ă, ă=aw, u=oo). These may all be pronounced either *short* or *long*, and may be variously modified, e. g. ü, French nasal modifications, &c. Two vowels coming together are called diphthongs, and are usually pronounced rapidly. (The English î is a diphthong ; the w a rapid contracted oo ; y *often* a rapid e ; â short is the English ɔ̃, á short=ü). Consonants are of three classes—

Phoneänta or breathings (no contact), ' , ' (=h), ch (German), gh, y (hard), s, z, sh, zh, th, dh, f, v, wh (hard).

Hemiphona or trills (slight contact), r (lingual), r (guttural), bw (labial r) l, ll (Welsh).

Aphona, checks or mutes (complete contact). Guttural. Dental. Labial.

Hard	k	t	p
Soft	g (hard)	d	b
Nasal	ng	n	m

Also aspirated mutes, kh (χ), &c., gh, &c., now generally pronounced as rough aspirates, (thus χ about = ch German, and gh = g final in German).

Hard letters are also called *tenues*, or *surd* (sharp), soft ones, *mediæ* or *sonant* (dull). Hard letters may be pronounced very hard, in an explosive manner. Between many letters the only difference is a sonorous and unvarying prefix, which also slightly softens the succeeding noise, e.g. t and d, the latter being the sonant, thus—

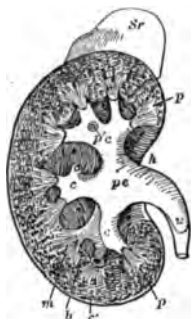
Surds, p, t, k, s, sh, ch = tsh, th, f.
Sonants, b, d, g, z, zh, j = dsh, dh, v.

The nasal prefixes are really nasal vowels. As generally pronounced ' is common to all open vowels (which commence words). Wh and y are whispered u and i respectively. Some consonants may be pronounced in two ways, e.g. the lingual Welsh r, and the guttural Parisian r, the Bohemian r combines the two : g (and also k) may be trilled so as to resemble somewhat a guttural r : most of the letters are pronounced in slightly different ways

in the various languages and dialects. Man is not the only animal which articulates his voice, e. g. B with sheep, whilst the vowels and most of the consonants have been recognized in birds. In man the capacity varies; thus, in Hindustani, there are forty-eight *consonants*; in some Polynesian dialects, ten or less; some Australian ones, eight; but it is to be remembered that there are different modes of intonation sometimes,—especially in Chinese. All sounds are not laryngeal,—e. g. whistling.

91. The *kidneys* are two peculiarly-shaped dark-brown bodies, with smooth surfaces, about $5 \times 2 \times 1$ in.: weight of both 11 oz.; the right is slightly the larger. They are situated inside the abdominal cavity, outside and behind the

FIG. 174.



Longitudinal section of right kidney.

sr supra-renal capsule. *h* hilus. *s, s* the sinus. *u* ureter. *pe* pelvis. *c* larger calyces. *m* medullary substances. *c'* cortical substance. *b* columns of Bertin. *p* a papilla projecting into a smaller calyx. *p'* summit of a papilla.

FIG. 175.

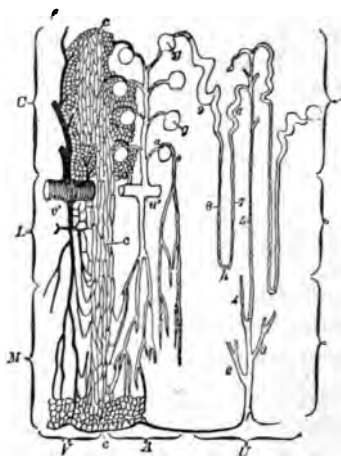


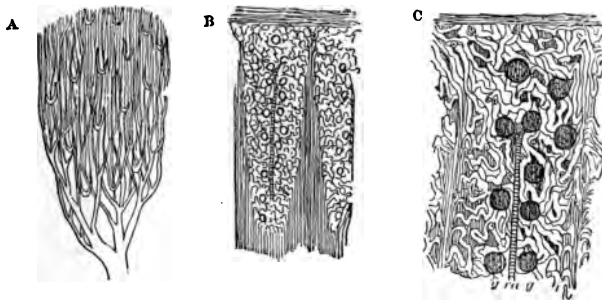
Diagram of the structure of the kidney.

M true medullary, *L* limiting medullary, and *C* cortical substances. *V* course and mode of bifurcation of veins *A* of arteries, and *U* of uriniferous tubes. *v'* and *e'* large artery and vein. *c, c* capillaries. *a* afferent and *e* efferent arteries of *g* glomeruli. *1* excretory canal. *2, 3, 4* primary, secondary, and tertiary branches. *5* straight tube of Bellini. *6* junctional tube. *7* ascending and *8* descending limb of *M. Heule's* loop. *9* convoluted commencing tube.

peritoneum, one on either side of the spinal column; the left behind the cardiac end of the stomach has its centre opposite the 12th dorsal vertebra, the right opposite the 1st

lumbar vertebra: they are kept in situ by areolar tissue and by the vessels connected with them. Each is invested with a fibro-areolar coat, which passes in and lines the sinus. On the inner border of each kidney is a fissure—the hilus—which extends inwards, forming a cavity, the sinus, in which are seen the pelvis and calyces. The parenchyma consists of two parts, a granular-looking cortical, and a striated medullary portion. The cortical, which is by far the greater portion, consists of the convoluted parts of the tubuli uriniferi, &c.; small bundles of straight tubes pass upwards into it, forming, together with the convoluted substance enveloping them, the pyramids of Ferrein; a little convoluted substance also penetrates inwards, surrounding and sepa-

FIG. 176.

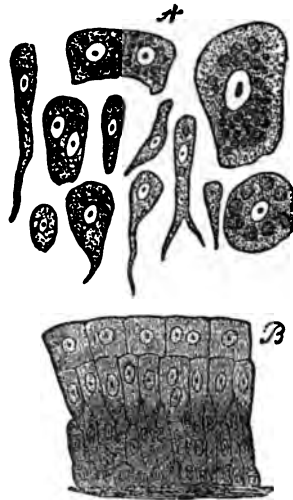
*Structure of kidney.*

A medullary substance. B cortical substance (one and a half pyramids of Ferrein).
C cortical substance, more highly magnified. *ra* renal artery. *g* glomeruli.

rating the Malpighian pyramids: these processes are called the columns of Bertin. The medullary portion consists of straight tubules, which are gathered into masses termed Malpighian pyramids, 12 (8—15), two or three of the apices of which combine to form each renal papilla, which projects into a calyx, or infundibulum; several calyces unite to form a larger calyx; the larger calyces, three in number, unite to form the pelvis, which may also be considered as the dilated upper extremity of the ureter or efferent duct, by which the urine leaves the kidney at the hilus,—the deep notch on the inner concave border, above mentioned. The commencement of the ureter is termed the pelvis. The urine passes down the ureters (each 16 in. long), which enter in an

oblique manner through the wall of the base of the urethrum or *bladder*, a hollow conical bag situated in the pelvis, coated by peritoneum, and capable of holding from one to

FIG. 177.



Epithelium from kidney pelvis. (Kölliker.)
A detached cells. B epithelium.

FIG. 178.



The bladder (seen from the left side, showing the outer layer of muscular fibres).
u urachus. p prostate. v vasa deferentia and vesicular ducts.

FIG. 179.



Epithelial cells from bladder.
(Rabbit sp.)

a flattened cell from superficial layer, showing ridges and depressions on under surface.
b superficial cell viewed sideways, showing c a pyriform cell fitting into it.

three pints: from the bladder it passes down the urethra, and thence out of the body. The *ureters* consist of (1) an

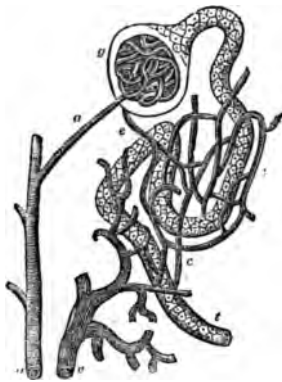
external fibrous coat, (2) a muscular coat of smooth fibres (with a very few striated ones), external longitudinal (absent high up), middle circular, and internal longitudinal layers; (3) a mucous membrane: the epithelium in three layers; outer free cells flattened, with depressions below, fitting upon the middle columnar cells, each of which sends a process downwards between the small spherical lower ones, of which there are sometimes two or three layers. The *bladder*, or *urethrum*, has a similar structure, the fibrous coat being derived from the peritoneum, and the muscular layers being thicker,—the fibres more or less transverse and spiral, and interlacing in a very complicate manner. Some believe that the muscles of the bladder may be divisible into two antagonistic sets, detrusor and sphincter,—the central layer being the sphincter; others doubt this latter function, and think that the urethral muscles serve as a sphincter.

92. The urine seems to be retained in the bladder by its elasticity: when the bladder is full, the muscular fibres are irritated and contract, expelling a few drops into the prostatic urethra, then the abdominal muscles contract and aid the (chiefly) involuntary fibres of the bladder in expelling the urine,—the final drops being ejected in a rhythmical jerking manner by the urethral muscles. During micturition (urination, or the expulsion of urine), and during defœcation, the abdominal muscles and the diaphragm contract, so that the intestines are pressed down upon the bladder and rectum, expelling the contents of one or other, as the case may be. The weight of the excreta aids slightly in both cases: the peristaltic action of the intestines more so (in the latter). The closure of the glottis, though more effective and comfortable when the diaphragm is required to be contracted, is by no means necessary; when not closed the respiration is purely thoracic. Both these acts are reflex, the expulsive action overcoming and paralyzing the retentive one, but being itself to a considerable extent under the control of the will.

93. The tubules in the medullary portion of the kidney, as they recede from their mouths, bifurcate repeatedly (especially at first), and occasionally anastomose; when they

arrive in the outer cortical portion they are convoluted, then pass downwards into the pyramids and up again into the cortex, thus forming the loops of Henle, again becoming convoluted in the cortical portion, where they terminate in rounded dilatations,—the Malpighian corpuscles or M. bodies, $\frac{1}{16}$ in. diam., which are thus formed: an afferent arterial twig enters a capsule and splits up into branches which may bifurcate several times, forming loops which do not anastomose; these smaller tubes form a convoluted mass, termed

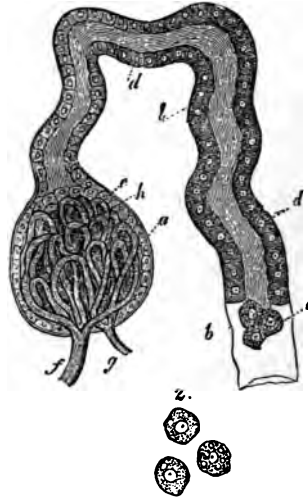
FIG. 180.



A glomerulus with its blood-vessels. (After Todd and Bowman.)

a artery. *a'* afferent arteriole. *g* glomerulus in Malpighian corpuscle. *e* efferent arteriole. *c, c* capillary network. *v* vein. *t, t* renal tubule.

FIG. 181.



Section of Malpighian body and part of tubule. (Kölliker.)

a capsule continuous with *b* membrana propria. *c, d* epithelium. *e* detached epithelial cells, seen more highly magnified at 2. *f* afferent artery. *g* efferent artery. *h* convoluted vessels forming the glomerulus.

a glomerulus, again uniting to form a single efferent arterial twig, which passes out close to the afferent one, and then enters the capillary plexus surrounding the tubules themselves. The tubuli and the capsules consist of a basement membrane of flattened cells, lined by a glandular epithelium; the glomerulus in the foetus is also surrounded on all sides by a layer of very minute glandular cells, which in the adult seems to unite with the capsular epithelium forming a

single layer,—being only present as such at the commencement of the tubule, and rarely dipping down into the tuft also. The outer portion of the medullary substance is sometimes called the limiting portion; in it run the arteries and veins, which send out minute branches on either side; the tubes anastomose here but rarely, and the greater

FIG. 182.



Vessels of a glomerulus of kidney.
A as usually seen. B as seen if unravelled.

portion of Henle's loops are found in it. The glomeruli are supposed to draw off water only, which passes down the tubuli, washing down their secretions, which are tolerably thick, containing all the solid matters.

94. Urine is normally rather acid when secreted, (but soon ferments—then becoming alkaline), and of a pale, yellow colour. About 50—52 oz. (35—81) are excreted daily: sp. g. 1·017—1·020 (1·025 in summer, 1·015 in winter; being, however, less in quantity during summer). It contains water 957, solids 43. Its chief constituents are urea, of which about 512 grains are daily secreted, and uric or lithic acid 8·5 grains, both nitrogenous compounds; kreatin, kreatinine, hippuric acid, alcohol, fixed salts, &c., are also found. The amount of urea depends upon the amount of nitrogenous food taken. It is also generally believed that exercise (both mental and bodily) increases it slightly, urea being then a symptom of waste of tissue, so that the amount of urea depends upon both food and exercise. In fasting animals there is an excess of uric acid, there being then a great consumption of (nitrogenous) tissues. Animal food tends to make the urine acid, scanty, heavy, and high-coloured,—vegetable food to make it alkaline, copious, light, and pale. The kidneys are most liberally supplied with blood; some calculate the supply as about 200 times as great as that of other parts of equal size: hence one cause of the bright

colour of their venous blood; but the venous blood also contains a *diminished* quantity of carbonic acid.

95. *Ductless glands*.—There are in the body certain ductless glands, whose functions are unknown. Being devoid of ducts, and being well supplied with blood-vessels and lymphatics, they are supposed to exercise some elaborative or other influence upon the blood, or lymph, and are therefore termed ‘vascular glands.’ Their functions are probably somewhat similar to those of the lymphatic glands, since some naturally disappear, whilst the most important,—the spleen, may be extirpated without destroying life. The ductless glands are the spleen, the thyroid body, the thymus gland, the two supra-renal capsules, the pituitary body, the coccygean gland, and the inter-carotid ganglion. The vascular organs might be classified into three groups.

A. Rudimentary racemose glands. Thyroid gland.

B. Lymphoid organs	{	1. Diffuse lymphoid infiltration. Adenoid tissue.
		2. Circumscribed lymphoid infiltration. Closed follicles. Tonsils.
		3. True lymphoid organs. Thymus. Lymphatic glands. Spleen.

C. Nervous glands. Supra-renal capsules. Pituitary gland. Pineal gland. Coccygeal gland. Inter-carotid gland.

96. The *spleen* is a dark, purplish kidney-shaped body, 5 × 3 × 1 in., weight 6 oz. It is situated immediately behind the left side of the stomach, being held in its place by two folds of the peritoneum. It is greatly distensible, and is much larger (and heavier) about six hours after the ingestion of food. It consists of an external capsule, which sends in a network of elastic bars,—trabeculæ, which traverse the whole interior. These consist of connective-tissue corpuscles, with much elastic fibre, and a few non-striated fibres. In the interstices between the trabeculæ is the dark purple splenic pulp, consisting of a mass of cells of various kinds, caudate cells, nucleated corpuscles of various sizes (the larger having several nuclei), free nuclei, granules, granular red cells, red corpuscles enclosed in nucleated cells, numerous red corpuscles free,—many in various stages of disintegration. There are also found in the pulp little whitish gelatinous oval bodies, the splenic or Malpighian

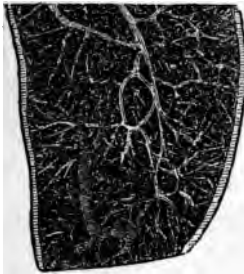
corpuscles, $\frac{1}{10}$ in. diam. These are situated upon the arterioles, and in man are usually pedunculated. They consist of a mass of nucleated cells and granules. The lymphatics of the spleen supply the arteries and veins with a tunica

FIG. 184.



Portion of spleen. (Showing Malpighian corpuscles. Kölliker.)

FIG. 183.



Portion of spleen substance. (Showing the trabeculae, the pulp being washed away. Kölliker.)

adventitia,—here a reticulated coat which communicates with the pulp, and finally becomes continuous with the trabeculae. The Malpighian corpuscles are simply bulbous expansions of this coat, and have no other envelope; sometimes they develop upon one side of the arteriole, sometimes all round

FIG. 185.

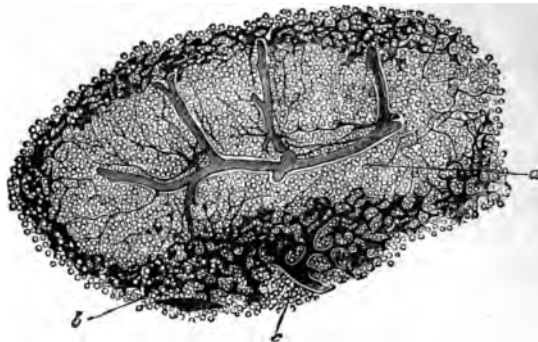


Small splenic artery with Malpighian corpuscles attached. (Dog. Kölliker.)

it. The true arterial sheath of the smallest arterioles becomes gradually fibrillated, and the fibres become continuous with the trabeculae. The veins possess a capillary system possessed of incomplete walls, and having the nuclei of their epithelium pediculated and projecting into the tubes, and

gradually passing into the trabecular nuclei. Between the (venous) capillaries and the arteries are the intermediate canals,—a continuation of the capillary system, forming a network of passages without walls throughout the pulp. Thus the spleen resembles a great lymph-gland, blood (+ some lymph) supplying the place of lymph, the arteries being the afferent, and the veins the efferent ducts, the pulp the central pulp, and the intermediate canals the lymph sinus. One or two (up to 23) minute accessory spleens, splenuli, are commonly found near: these are of the size of a pea upwards. After passing through the spleen, the blood is found to possess *more white corpuscles* (becoming in propor-

FIG. 186.



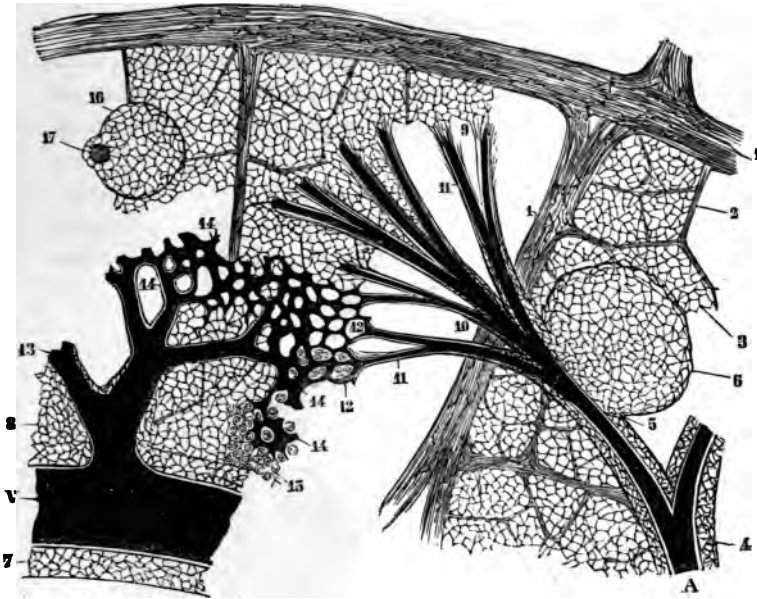
Malpighian corpuscle of spleen. (Hedgehog. W. Müller.)

a corpuscle, consisting of cells, with a vascular supply. *b* splenic pulp, with inter-cellular blood-passages. *c* commencement of a vein.

tion to the red as 1:70) and fibrin, but less (some say more) red corpuscles, and the blood coming from it also contains less solid matter, and has the serum of a reddish colour. Hence it is supposed that the spleen (1) forms white corpuscles: N.B., Leucocythæmia, a disease of the spleen in which the number of white corpuscles in the blood is vastly increased (1 white to 7 red); (2) as a blood-filter, detaining and destroying (effete) red corpuscles, hence the colour of the venous serum; (3) perhaps also a former of red corpuscles; (4) possibly a regenerator of semi-effete corpuscles, the red ones becoming smaller, firmer, and more nearly spherical, a portion of their contents having exuded, hence another

cause of the colour of the serum ; (5) as a blood-receptacle during digestion (perhaps regulating the amount sent, and)

FIG. 187.



Semi-diagrammatic representation of the structure of the spleen. (Beaunis et Bouchard.)

A artery. V vein. 1 splenic trabeculae. 2 finer ones. 3 reticulum or network of the pulp. 4 lymphoid infiltration of arterial coat. 5 its continuation into 6 a Malpighian corpuscle. 7 coat of vein. 8 network. 9 termination of the fibrillar coat of arterial capillaries in the reticulum. 10 arterioles. 11 the arterial capillaries which at 12 open into the intermediate passages of the pulp. 13 veins. 14 venous capillaries. 15 pulp with cells remaining. 16 a Malpighian corpuscle seen in section, surrounding 17 an artery.

relieving the intestines from overcharge. The blood from the spleen goes to the portal vein.

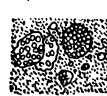
97. The *thyroid* body, situated in the throat, lies against

FIG. 188.



Three thyroid vesicles.

FIG. 189.



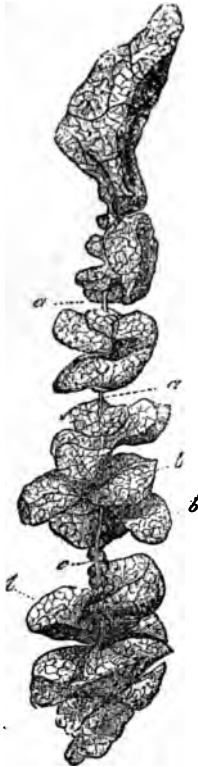
Thymus juice, showing corpuscles granules, and base.

the top of the trachea. It consists of two lateral lobes connected by an isthmus. It weighs from 1 to 2 oz. ; it is

rather larger in women than in men; when enlarged by disease it gives rise to goître. It consists of a mass of vesicles filled with nucleated cells, granular nuclei (= 'dotted cells' of some authors), and fluid,—all derived from an original epithelial layer, sometimes present, but unsupported by *membrana propria*; the vesicles are embedded in areolar tissue, and surrounded by rich networks of capillaries.

98. The *thymus* body or gland is situated at the base of

FIG. 190.



Portion of thymus unfolded. (Calf. Kölliker.)

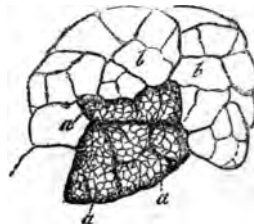
a, a main canal. b glandular lobules.
c isolated gland-granules upon canal.

FIG. 191.



Section of thymus. (Man. Kölliker.)
Showing central cavity laid open, communicating with the lobular cavities.

FIG. 192.

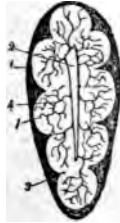


Lobules of thymus. (Kölliker.)
a, a acini or gland-granules uniting to form b, b lobules.

the neck and top of the thorax, lying behind the sternum,

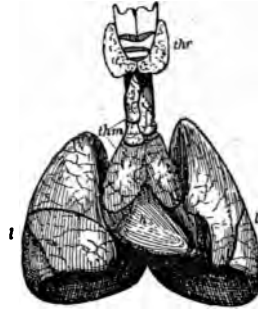
and resting upon the aortic arch : weight at birth $\frac{1}{2}$ oz. It is composed of primary and secondary lobules all developed around a central stem, which assumes a spiral shape,—all the lobules and stem being hollow and communicating so as to form an irregular cavity : the lobular vesicles are not lined by an epithelium, and have a retiform network in the interior throughout their substance, in the meshes of which are 'dotted' cell-nuclei,—mostly (or all) enclosed in cells, which must have a very delicate, if any, envelope. Probably these contents are not lymph : a few scattered concentrically-striated corpuscles are also found. Some think that septa which incompletely divide the retiform tissue into several

FIG. 193.

*A thymus lobule.*

Divided into 1 acini, 2 central canal,
3 lobular investment, 4 arteries.

FIG. 194.

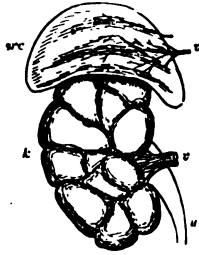


Thymus and thyroid glands, of fetus.
thr thyroid gland. *thm* thymus. *h* heart.
l, l lungs.

capsules or lobules may be complete, but in the interior, being easily torn, &c., give rise to the appearance of a central cavity. The arteries run in the centres of the acini,—the veins in the peripheries. The thyroid is at its largest in the foetus, the thymus about two years after birth ; both soon diminish, and the thymus generally, and thyroid occasionally, disappear in the adult. In the foetus both are intimately connected, but always differ histologically.

99. The *supra-renal capsules* are two yellowish sacs, which are attached by areolar tissue to the upper ends of the kidneys : weight of each, 2 dr. They are well-supplied with blood-vessels, and very many sympathetic nerve-fibres.

FIG. 195.



Supra-renal capsule and kidney of six months' fetus.

are supra-renal capsule. k kidney, showing lobular divisions. u ureter. v, v veins.

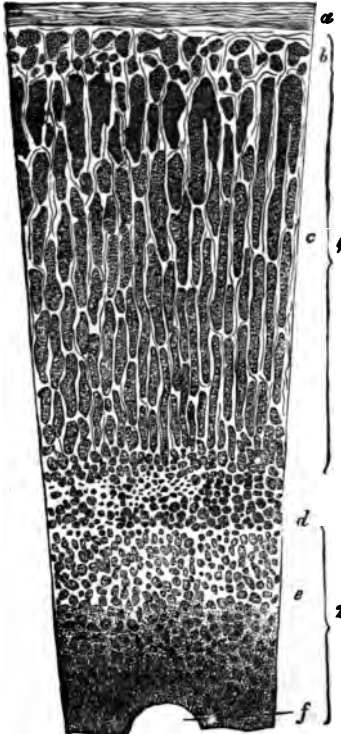
FIG. 196.



Section of right supra-renal capsule of fetus. Showing cortical and medullary substances.

h hilus. v, v veins. o outer or posterior surface. n notch receiving summit of kidney.

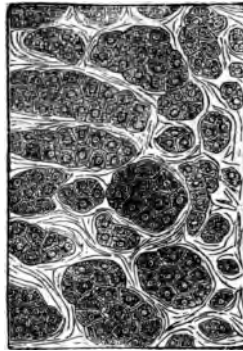
FIG. 197.



Section of supra-renal capsule. (Eberth.)

1 cortical substance. 2 medullary substance. a fibrous sheath. b zona glomerulosa. c zona fasciculata. d zona reticularis. e medullary cells. f a vein.

FIG. 193.



Substance of zona glomerulosa. Showing cell-groups and cells. (Eberth.)

Each is divisible into a cortical, and a smaller medullary portion. The cortical portion consists of a fibrous matrix, in which are embedded vesicles,—the ‘cortical cells,’ usually (if not always) without proper walls (of *membrana propria*), and containing (1) dotted nuclei, granules, and oily globules, and also (2) cells containing any or all of these elements. The vesicles are oblong, cylindrical, and radiate lengthways from the centre,—the most external and internal being spherical, thus forming three zones, of which the central is by far the largest. These are the *zona glomerulosa* (ext.), *z. fasciculata* (mid), and *z. reticularis* (int.). A layer of connective-tissue divides the cortical and medullary portions: in the adult the medullary portion shrinks, and is absent at parts, so that the areolar tissue there forms processes which project into the cortical part. The medullary portion is areolar, and has its interspaces filled (1) with cells, which are sometimes branched, and are supposed by some to be (nerve-) ganglionic, and also (2) with nuclei and granules. The supra-renal capsules are largest during the embryonic stage. They are found diseased in cases of ‘bronzed skin.’

100. The *pituitary body* or gland is divisible into two lobes, a larger anterior and smaller posterior. The posterior is a prolongation of the infundibulum, and contains nerve-

FIG. 189.

*Section of the pituitary body.*

a anterior lobe, with transverse canal and radiating vesicles. *p* posterior lobe.

cells. The anterior is a peculiar structure: it contains a transverse central canal, lined with ciliated epithelium; in front of this are several capsules filled with colloid matter, and resembling degenerating thyroid capsules; behind it are several radiating vesicles, containing irregular cells.

101. The *pineal gland*, besides nervous elements at its base, contains two or three vesicles, which enclose granular cells, a gritty matter termed *acervulus cerebri*, and some gritty fluid: the *acervulus* consists of amylaceous

substance (found elsewhere in the brain), and earthy salts. The connexion of the nervous elements with the gland-substance is unknown.

102. The *coccygean gland* of Luschka consists of vesicles and glandular tubules, filled with polygonal epithelium; these vesicles and tubules are very probably connected with the arteries,—are modified dilatations of arterioles, though some consider both this and the inter-carotid ganglion as probably nervous in function.

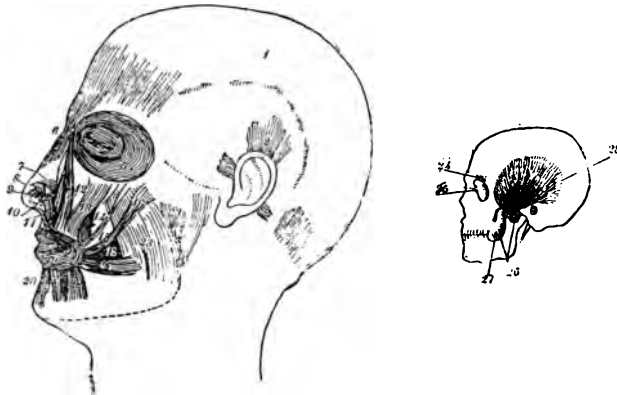
103. The *inter-carotid ganglion* has a structure similar to that of the coccygean gland.

CHAPTER V.

THE MUSCULAR AND OSSEOUS SYSTEMS.

104. THE function of the (striated) muscles is the movement of parts or the whole of the body; this is generally done by the medium of the bones. A muscle consists of a bundle of parallel fasciculi of striated fibre; but the longest individual fibres are not more than $1\frac{1}{2}$ in. Muscles commonly bulge at the centre, and taper at the extremities, to each of which is usually attached a very tough inextensible cord of

FIG. 200.



The muscles of the head.

1, 1 occipito-frontalis. 1' its tendinous portion. 2, 3, 4 attollens, attrahens, and retrahens aurem. 5 orbicularis palpebrarum. 6 pyramidalis nasi. 7 compressor naris. 8, 10 levatores alae nasi, anterior and posterior. 9 lesser compressor narium. 12 levator labii superioris alaeque nasi. 13 levator labii superioris. 14 levator anguli oris. 15, 16 zygomaticus minor and major. 17 risorius. 18 buccinator. 19 orbicularis oris. 20 depressor anguli oris. 21 levator and depressor labii inferioris. 22 depressor anguli oris. 23, 23 masseter. 24 corrugator supercilii. 25 tensor tarsi or Horner's muscle. 26, 27 external and internal pterygoid. 28 temporal.

white fibre—a tendon. The extremity which is attached to the bone to-be-moved is called the insertion—the other extremity, which in the limbs is always nearer the trunk, the origin—the intermediate part, if thick and bulging, the belly. The muscles of the limbs are usually somewhat spindle-shaped as above described, but those of the body

are mostly more or less *flattened out*,—sometimes into a layer, either like a ribbon (e.g. the intercostals, the fibres then running transversely or diagonally), or radiating round an orifice. A muscle may have more than one point of origin or insertion, or both, e.g. the triceps, or extensor muscle at the back of the upper arm (and which is the pugilistic or striking muscle, and *not*, as is popularly supposed, the biceps in front, which is flexor, and used more in rowing): a muscle may have two bellies and an intermediate tendinous part.

105. Muscles are named according to their (1) Shape: thus there are orbicular or sphincter muscles which surround, and by their contraction close certain orifices; such are the muscles of the eyelids, lips, anus, &c.: there are also deltoids, recti, &c. (2) Position: there are brachial, pectoral, abdominal, &c. (3) Division—according to number of origins or insertions: as biceps, in which there are two, and triceps three origins. (4) Function: as flexors, extensors, levators, adductors, and abductors. The number of muscles in the body is variously calculated, because some have several points of origin, &c., whilst orbicular and flattened muscles may have many points of origin and insertion (the details also differ slightly in different individuals): there are *about* 400. The muscles are generally arranged in *pairs*,—each pair consisting of two antagonistic muscles, one for bending, or flexing the limb, the other for extending it; one thus rests while the other works.

106. Muscles act by contraction,—the body of the muscle becoming shorter and thicker, and thus drawing together the parts to which are attached its origin and insertion. Only parts of a muscle contract at a time, the contracting fibres sometimes presenting a zigzag appearance. Striated fibres contract to about $\frac{2}{3}$ of their length (non-striated to $\frac{1}{3}$); but they do not diminish in actual bulk (or but to an extremely slight degree). Some muscles only act when directed by the will, these are termed *voluntary*; some, such as those of the heart, and to a certain extent those of respiration also, are *involuntary*, acting independently of the will, though under more or less limited control. Except

when asleep, and when lying down, more or less of the muscles of the body are in a state of statical tension (caused by antagonistic muscles counterbalancing each other). N.B., when a person is standing perfectly 'at ease,' the muscles of the back and legs become tired. We thus see that the state of the muscles is essentially one of alternate action and repose. Muscular fibre is, however, always in a state of *slight* tension or tonicity, giving the firmness to the muscles of a healthy man. Muscular contraction evolves heat, raising the tissue 1° or 2° F., making it acid, and decomposing some particles. Muscle, when contracting, vibrates *about* 19.5 (19—45) times per sec., causing a susurrus or hum of 39 vibrations (32—45),—the octave harmonic of 19.5. Muscular contractility is distinct from nervous irritability, for muscular tissue is capable of contraction under galvanic influence when the nerves are cut away. Muscles lose about 35 per cent. of their force by friction of their tendons. One grain of muscle can perform 10 oz. (7—16) of work. Muscle consists of about 74.4 water; its solid constituents (25.6) are about the same as those of blood. C 52.8, H 7.25, N 15, O 21.3, ashes 4.2: sp. g. 1.020.

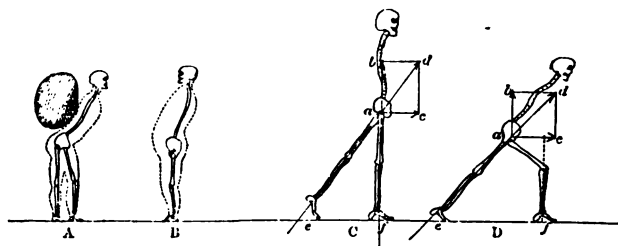
107. Walking is the natural mode of progression of man. Each step may be divided into two periods; one (s) when the foot is upon the ground, the other (m) when it is in motion. In slow walking there is a period when both feet are upon the ground at the same time; this period gradually diminishes as the pace becomes more rapid, until finally, in running, there is a time when both feet are off the ground.

Slow march	{	L	M	S	S	S	M	S	S	S
	{	R	S	S	M	S	S	S	M	S
Quick march	{	L	M	S	M	S				
	{	R	S	M	S	M				
Running	{	L	M	M	M	S	M	M	M	S
	{	R	M	S	M	M	M	S	M	M

The resultant of the force exerted by the fore-leg is vertical only. The resultant of the force exerted by the hinder leg may be resolved into two components,—one vertical, which aids the fore-leg in supporting the weight of the body, both together having a constant value,—the other horizontal, which

projects the body forwards: hence the greater inclination of the body forwards, as well as the greater force used in

FIG. 201.



A position assumed by a person carrying a weight upon his back. B position of a fat person. C $a b$ the resultant of the force $e a$, may be resolved into a horizontal component $a c$, and a vertical one $a b$. $a b$ and $a f$ support the body, $a c$ impels. D the position in rapid walking; $e a$ remaining the same, $a c$, $a f$ are increased, $a b$ diminished.

rapid walking, thus increasing the length of the horizontal component.

108. The bones are attached to each other by various *ligaments*, of which those of the spinal column are the only

FIG. 202.

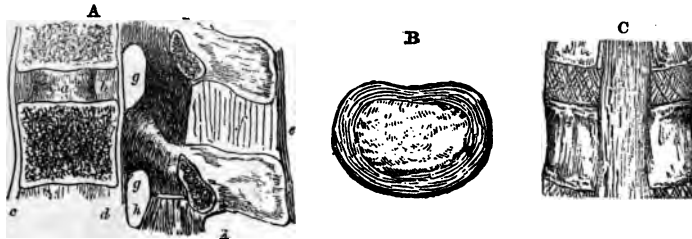


Ligaments. Anterior surface of right wrist.

ones which command any particular attention. The vertebræ are strapped together by five sets of ligaments, besides other small or unimportant ones, e. g. the capsular ligaments of the articular surfaces, &c. (1) The anterior common ligament running down the anterior convex side of the column; by it each centrum is fastened to the one next to it, to every 3rd vertebra by a series over these, and to every 4th or 5th by a higher series; (2) common posterior ligament, forming a similar system, connecting the posterior surfaces of the centra, and so being enclosed in the anterior

part of the spinal canal; (3) inter-spinous ligament, another similar system connecting the spinous processes of

FIG. 203.



Ligaments and intervertebral discs of spine.

A side view. *a* pulpy part of disc. *b* fibrous tissue. *c* anterior common ligament. *d* posterior common l. *e* supra-spinous l. *f* inter-spinous l. *g* ligamenta subflava. *h* capsular l., and *i* inter-transverse l. (both seen where *g* and *f* are removed). B transverse section of disc showing pulpy and fibrous portions. C front view showing anterior common ligament and fibrous rings of disc.

the dorsal and lumbar vertebræ; (4) supra-spinous ligament, which, with its cervical continuation; (4a) termed the ligamentum nuchæ, connects the ends of the spines of the dorsal and lumbar vertebræ; (5) ligamenta subflava, which connect the neural arches of the moveable vertebræ.

109. *Periosteum*, which covers all the bones, serves as a medium of attachment for muscles, tendons and ligaments, and for ramification of the arteries before entering the bone; it also supplies a very smooth surface, thereby lessening friction.

110. When the ends of bones glide on each other, they are covered by articular cartilage, and between them is interposed an imperfect sac, filled with a glairy fluid identical with lymph plasma: these are the *synovial membranes*, and the fluid, *synovia*. Synovial membranes are a modification of serous membranes. Their free part generally has a fringed appearance, owing to little tufts projecting into the cavity; these are processes of the walls. (1) The Haversian folds and fringes, which are vascular and contain fat, and (2) the secondary fringes of Rainey, which are smaller and non-vascular: they are finger-shaped, and project from the Haversian fringes, &c. The walls are composed of vascular connective-tissue; here and there the cells congregate, forming epithelioid patches of flattened serous-like cells, which near the edge of the group become scattered and

branched, passing into the ordinary branched cells; these epithelioid cells seem to be the descendants of the superficial cartilage cells lining the articulating surfaces. Synovial membranes are of three varieties. (1) Articular, between

FIG. 204.



Synovial membranes.

1 articular. 2 bursa. 3 vagina. *b* bone.
t tendon. 4 wall of synovial sac.
a a larger fringed process. *a'* another
 covered with smaller ones.

FIG. 205.



Synovial epithelium from the border of an
 epithelioid patch. Showing cell-
 transition.

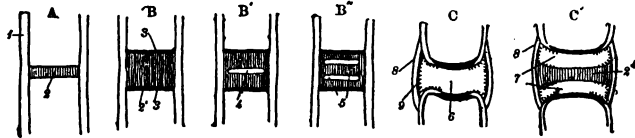
joints, are sacs sometimes of an hour-glass shape; their attached parts furnish the articular cartilage with a complete epithelium in the foetus, but this is absent from the central part in the adult, the cells shading off gradually into cartilage-cells, though it forms a tolerably regular epithelium in the other parts; the periosteum is absent at the articulating surfaces: (2) Bursæ, little sacs between two surfaces, as where a tendon glides over a bone. (3) Sheaths or vaginal synovial membranes, similar to bursæ, but enclosing a part of the tendon: sometimes, as in the wrist, several bones are supplied by one common synovial sac. Were it not for the synovia, the smooth articular surfaces would 'bite'—cohere, on account of atmospheric pressure, which exerts considerable influence in holding together the bones and preventing dislocation, there being about 14 lbs. pressure to each square inch of contiguity of surfaces. The total atmospheric pressure sustained by the body (surface) is about 13 tons.

111. A joint or articulation is the union of two bones. Bones are articulated in three ways, of which there are several varieties.

<i>Synarthrosis</i> (immoveable)	{	Sutura, indented borders which dove-tail, e. g. parietal bones.
		Harmonia, apposition of rough surfaces, e. g. superior maxillaries.
		Schindylesis, bevelled surfaces, e. g. vomer, rostrum.
		Gomphosis, lodged in cavities, e. g. teeth.
<i>Amphiarthrosis</i> (slightly moveable)	{	(slightly moveable), very limited gliding, e. g. vertebræ.
<i>Diarthrosis</i> (moveable)	{	Arthrodia, gliding, e. g. carpals.
		Ginglymus, hinge, e. g. elbow, phalanges.
		Enarthrosis, ball and socket, e. g. hip.
		Rotatorius, pivot, e. g. atlas and axis.

In synarthrosis the bones are firmly united by *sutures*, the periosteum passing from bone to bone, and a kind of periosteum, the sutural ligament, also passing in between them. In amphiarthrosis the periosteum of both bones is also continuous, but the ends are tipped with cartilage, and between the two ends is interposed a disc, which sometimes contains a cavity (rarely two) which does not possess a synovial lining: the ends of the bones are thus united by flat bands or discs of cartilage or fibro-cartilage, which allow of very limited motion

FIG. 206.



Articulations.

A synarthrosis. B B' B'' amphiarthrosis. C C' diarthrosis.

1 periosteum. 2 internal ligament. 2' interarticular ligament. 2'' interarticular disc.
3 articular cartilage. 4, 5 cavities. 6, 7 synovial discs. 8 fibrous capsule.
9 synovial epithelium.

in all directions. In diarthrosis, the joints are tipped with articular cartilage, and possess synovial sacs: occasionally moveable discs of fibro-cartilage are interposed between the joints, there being then two synovial sacs: the bones are checked from too great mobility by ligaments, thus more or less limiting the movements and the freedom of the joint.

112. Movements are of four kinds; (1) gliding, e. g. carpals; (2) angular or hinge, e. g. elbow; (3) circumductory, e. g. hip, moving leg around in a circle,—also the spinal column, as a whole, in moving the body; (4) rotatory, e. g. atlas upon axis.

113. All three kinds of levers are made use of in the body

by various muscles and bones. First kind, e. g. triceps and ulna in extending the arm. Second kind, e. g. gastrocnemius

FIG. 207.



Diagram showing how the three orders of levers are made use of in the body.
1 example of the 1st order. 2, 2nd order. 3, 3rd order. The muscles are represented black, the bones are left white. *f* fulcrum. *p* power. *w* weight.

of 'calf' and os calcis of heel in lifting the heel (and body) in walking. Third kind e. g. biceps and radius in flexing the arm. In levers of the first kind the power arm, to which the power, i. e. the muscle, is attached, is generally the shorter, thus sacrificing strength to quickness of motion. Muscles are generally attached very obliquely, and thus act at a great disadvantage; but the enlarged extremities of many of the bones over which the tendons have to pass, act as fixed pulleys, thereby causing the muscles to act more perpendicularly, and so to a greater advantage. In other cases bony ridges, tubercles, &c., are advantageous, generally by increasing the length of the power arm.

114. The bones serve for holding the various parts of the body in situ, and afford bases of operation for the muscles. They are composed of bony tissue, the earthy matter of which increases during the whole of life. They may be divided into four classes according to their shape.

Long bones, each consisting of a cylindrical shaft which is hollow, the cavity containing marrow. Much cancellated tissue is found near the ends of the long bones: the spiculæ are arranged perpendicularly to the strain, so as to form supporting columns to the compact tissue, a layer of which of varied thickness always covers the cancellated tissue externally,—the cancellated tissue gradually passing into it on the one hand, and becoming more scanty, and disappearing in the marrow on the other, e. g. humerus, femur.

Short bones are mainly composed of cancellated tissue, covered with a layer of compact tissue, e. g. carpals.

Flat or *tabular* bones, more or less irregular, as the parietal bones, and scapula.

Irregular bones, as the ethmoid, hyoid, and the vertebræ. The two latter kinds are composed similarly to the short bones.

115. The surfaces of bones are variously modified, presenting (1) protuberances, or processes of various shapes and degrees of projection; these are termed ridges, tubercles, spiny processes, &c.; (2) foramina, or notches; (3) grooves; (4) cavities (if shallow, these are termed glenoid; if deep, cotyloid).

116. In development, bones arise from one or more points of ossification; these, by enlarging and spreading out,

FIG. 208.



The skeleton of man. (Agassiz and Gould. After Cheselden.)

gradually meet together, and coalesce by ankylosis, or soldering together, to form a single bone. As this takes place in the different bones at different periods of life, there is a slight doubt about the unity of one or two of the bones. The supplementary centres of ossification at the end of long bones are termed epiphyses; between these and the shaft, as long as growth continues, there is a layer of cartilage which renews itself as fast as the external parts become ossified. The long bones sometimes have as many as seven centres, and their bases remain for a long time separate. The flat bones, e. g. those of the skull, increase chiefly by growth at their edges.

117. The bony skeleton is bilaterally symmetrical, and consists of 204 bones, not including either the 32 *teeth*, which are not really bones, but enderonic appendages, or the *sesamoidal* bones. The bones may be conveniently divided into those of the head (29 in number), trunk (51), and limbs (124). The bones of the head may again be divided into those of the cranium, or skull itself (8), and those of the face (15), (also the six auditory ossicles).

118. The cranium contains a somewhat oval cavity, which

FIG. 209.



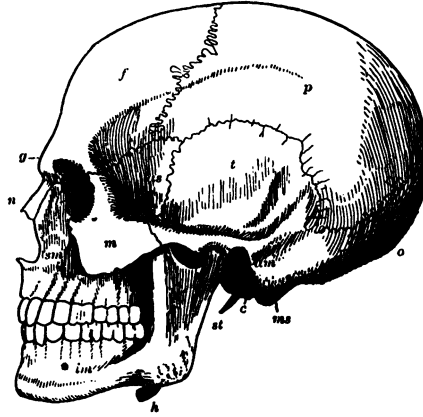
Skull, from before.

f frontal. *g* glabella. *p* parietal. *as* alisphenoid. *t* temporal. *n* nasal. *m* malar.
sm superior maxillary. *im* inferior maxillary.

encloses the brain. The greater part of the outer-wall bones

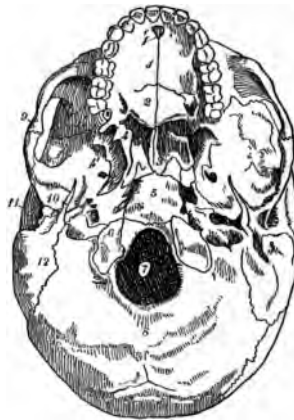
consist each of an outer thick layer of tough compact tissue, and an inner more dense and brittle layer,—termed the

FIG. 210.

*Skull, side view.*

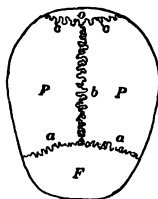
l lachrymal. *h* hyoid. *st* styloid process of temporal. *am* external auditory meatus. *ms* mastoid process. *o* occipital. *c* occipital condyle. Other letters as in preceding figure.

FIG. 212.

*Basilar view of base of skull.*

1 superior maxillaries. 1' anterior palatine canal. 2 palatal bones. 3 vomer. 4 4' internal and external pterygoid processes. 5 bodies of sphenoid and occipital. 6 condyles. 7 foramen magnum, shown black. 8 occipital bone. 9 9' zygomatic arch and fossa. 10 styloid process. 11 meatus auditorius externus. 12, 12 temporal bone.

FIG. 211.

*Calvarium.*

F frontal bone. *P, P* parietal bones. *O* occipital bone. *a* coronal suture, *b* sagittal suture, and *c* lambdoid suture.

vitreous table, both united by an intermediate spongy cancellated layer termed diploë: the outer tough layer, with

its elastic support, is intended to resist a blow from a blunt instrument, which would break a brittle layer if outermost, —the hard vitreous inner one to resist a pointed instrument

FIG. 213.

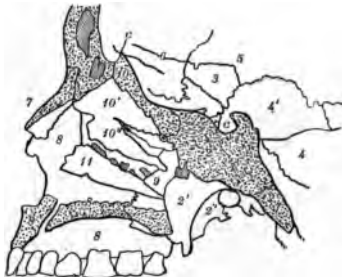


Vertical longitudinal section of skull, just to the left of the middle line.

a alisphenoid. *bo* basi-occipital. *bs* basi-sphenoid (with cells in front). *co* condyle. *f* frontal bone (and sinus). *h* hyoid. *lt* middle turbinal process. *m* mandible. *ma* meatus auditorius internus. *me* median ethmoid. *n* nasal. *oc* occipital. *p* parietal. *pt* palatine. *pt* petrosa-temporal. *pts* pterygoid processes of sphenoid. *s* styloid process. *sm* superior maxillary. *sq* squamosa-temporal. *v* vomer. *B* cranial cavity for brain. *B'* receives frontal lobe, *B''* temporal lobe, and *C* the cerebellum.

which might have passed (though with diminished force) through the outer layers: the sutures of the outer cranial wall are of the toothed, serrated, or crenated type; the

FIG. 214.



Longitudinal vertical section of basi-cranium.

1 basi-occipital. 2 basi-sphenoid. 2' inner and outer pterygoid processes. 3 its ala. 4, 4' petrosa- and squamosa-temporal. 5 parietal. 6 frontal. 7 nasal. 8 superior maxillary. 8' inter-maxillary portion. 9 palatal. 10 sphenoid. 10' upper and 10'' middle turbinated process. 11 inferior turbinated bone. *c* crista Galli. *s* sella turcica.

serræ are confined to the outer layer. The skull being composed of several bones, is thereby enabled to expand better in growth, and this possibly serves slightly better

as a protection against injuries. The wings of the sphenoid bone serve as tie-beams of a roof, overlapping and holding together the side-walls of the cranium. The suture between the (squamous portion of the) temporal and the parietal bones is termed the squamous suture,—the squamous bone being bevelled off and overlying the parietal bone, like a fish-scale.

FIG. 215.



Frontal bone from below. g glabella. o, o orbital roofs.

1 (F. 2)* The *frontal* bone, forming the forehead, has an external supra-orbital ridge—the glabella—along its base.

2, 3 (F., each 1). The *parietal* bones, form the main part of the roof.

4 (F. 7). The *occipital* bone forms the back part, and a portion of the base of the skull. In its base is a perforation—the foramen magnum—for the passage of the medulla oblongata. On either side of this orifice are two protuberances, the condyles.

FIG. 216.



Outer surface of occipital bone.

so squama. *bo* basilar part which unites with the basi-sphenoid. *c, c* the two condyles. *fm* foramen magnum.

FIG. 217.



Right temporal bone, outer aspect.

sq squamous. *z* zygomatic process. *m* mammillary. *m'* its mastoid protuberance. *s* styloid process. *a* meatus auditorius externus, nearly surrounded by the tympanic bone. *p* petrous.

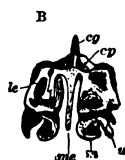
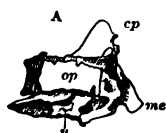
5, 6 (I. 4 [5 or 6 ?]). The *temporal* bones, one on either

* The letters and figures in brackets indicate respectively the shape of the bone, and the number of points of ossification from which it arises; thus (F. 4) signifies flat bone, 4 points.

side, each consisting of three portions (A), a flat *squamous* portion, which sends off in front a zygomatic process. Its lower surface presents a glenoid cavity. (B) the *petrous* portion is formed of very dense bone, and in it chiefly is situated the internal ear, containing three auditory ossicles: the *tympanic* bone forms part of the petrous portion, having become fused with it early: the tympanic bone forms an irregular incomplete ring round the external auditory canal. (C) the *mammillary* portion having a large *mastoid* protuberance: from it also projects a slender *styloid* process. The points of ossification are the squamous, petro-mastoid, tympanic, and styloid.

7 (I. 3). The *ethmoid* is a very complicate sieve-like bone, which forms part of the base of the cranial cavity. It is not externally visible, being situated behind the nasal bones. It consists of (A) a median transverse cribriform plate forming part of the cranial floor and nasal roof; from this a process

FIG. 218.



Ethmoid bone.

A right side. B posterior.
cg crista Galli. *cp* cribriform plate. *le* lateral ethmoid. *op* os planum. *u* unciform process. *s* superior, and *m* middle turbinate processes. *me* median ethmoid.

—the crista galli—projects upwards into the cranial cavity, and another larger one downwards—the median ethmoid—partly dividing the two nares, or nasal passages; (B and C) the two lateral ethmoids, depending from the transverse plate, and forming the greater part of the external wall: the upper and middle turbinals are folds of these.

8 (I. 12 [10 ?]). The *sphenoid* bone, also very complex, is situated between the ethmoid and occipital bones, forming part of the skull-base: thus the base of the skull is formed by the frontal bone (which at its base curves backwards over the orbits), the ethmoid, sphenoid, and occipital bones. The sphenoid bone consists of a body, two greater alæ (or wings), two lesser or orbital alæ, and two internal and two external pterygoid processes: the pterygoid processes pro-

ject downwards. Only parts of the greater alæ appear

FIG. 219.



The sphenoid bone from above.

ps presphenoid.
o orbital or lesser wing.
a alisphenoid or greater wing.
ep, ip external and internal pterygoid processes.
s sella turcica.
op groove for optic nerves.
bs basi-sphenoid.
bs' its surface of attachment to the basi-occipital.

externally (at the temples).

119. 9—14 (I.). The auditory ossicles (see Hearing), three on either side,—the malleus, incus, and stapes, are lodged in the petrosa-temporal bone.

120. The bones of the face (15 in number) are :

15, 16 (I. 4). The *superior maxillaries*, which unite together in front. In their lower border are embedded the upper teeth—8 in each. They form the cheeks, fore-part of the bony palate, &c. The central portion of each, in which are embedded the incisor teeth, is in some vertebrates separate, and is termed the præ- or inter-maxillary bone : the canine tooth is situated at its junction with the maxillary.

17, 18 (I. 1). The *malars*—situated at the lower external angle of the orbits. Each sends out two processes, (A) one upwards, forming part of the outer orbital wall, (B) one backwards to join the zygomatic process of the temporal, thus forming a bar, between which and the cranial wall is a space—the glenoid cavity.

19, 20 (F. 1). *Lachrymals*—two small bones, each in the inner wall of the orbit, and grooved for the lachrymal duct of its side.

21, 22 (F. 1). *Nasals*, two small bones, forming the 'bridge of the nose,'—the rest of the nasal skeleton in front, up to the point, being completed by cartilage.

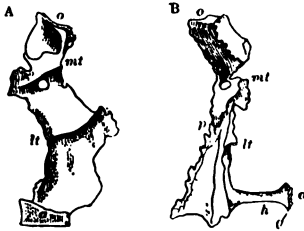
23 (F. 1). The *Vomer*, a vertical plate, which helps the median ethmoid to complete the partition between the two nares.

24, 25 (I. 1). The *Lower turbinals*, or *inferior turbinated*

bones, extend along the nasal fossæ, and are attached slightly to the superior maxillary and palatine bones.

26, 27 (I. 1). The *Palatine* or *palatal* bones are attached to each other and to the superior maxillaries. They form

FIG. 220.

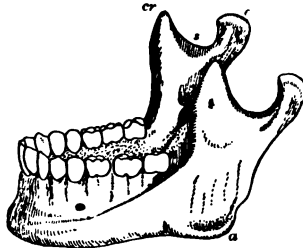
*Left palatine bone.*

A interior, B posterior view. *a* articulates with its fellow and receives the vomer. *s* half of palatine spine. *h* horizontal plate. *p* perpendicular plate. *lt*, *mt* crests for attachment of the lower and middle turbinate bones. *o* orbital surface.

the hind part of the bony palate, part of the roof and outer wall of the nasal cavity, and pass up to the orbits.

28 (I. 2). The *Mandible*, *inferior maxillary*, or lower jaw-bone, is (excepting the little hyoid bone) the only moveable bone of the face. It is somewhat like a horse-shoe in shape, and embedded in its upper border are the sixteen lower teeth. Its two halves or rami (separate in the embryo) are united

FIG. 221.

*Lower jaw.*

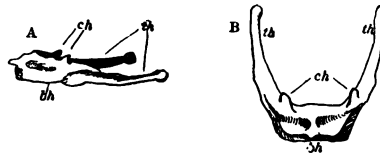
cr coronoid process. *s* sigmoid notch. *c* condyle. *a* angle.

by a complete symphysis: each bends upwards posteriorly at an obtuse angle, and ends in two processes; (A) the condyle by which it articulates with the skull, fitting into the glenoid cavity; and (B) a coronoid process just in front of this for the attachment of the temporal muscle: the other masticatory muscles are attached near the angle.

29 (I. 5 ?). The *hyoid* bone, a small horse-shoe-shaped bone, is capable of some indirect, but no very definite movement.

It is situated at the base of the tongue, and just above the larynx. It consists of (A) a thin oblong body (basi-hyal), convex forwards, concave backwards; (B) two rather long processes, the cornua (thyro-hyals) projecting backwards,

FIG. 222.



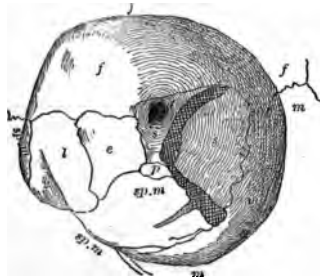
The os hyoides.

A side view. B view from above. bh body. ch cornicula. th cornua.

one from either side of the body; (C) two small ossicles, the cornicula (cerato-hyals), anchylosed to the body at its points of junction with the cornua: (they are *sometimes* attached by a synovial sac): they are attached by ligaments to the styloid processes of the temporal bones.

121. Several small cavities in the head must now be described. In each temporal bone is an auditory tympanic cavity (containing the three ossicles and adjoining labyrinth). The bones of the skull are at parts thick and hollowed out into cells: the frontal bone has two cavities or sinuses, one above each brow, and which are sometimes united: there are two small sphenoidal sinuses: in each superior maxillary is a cavity, antrum (of Highmore): in the mastoid bones, and in the lateral masses of the ethmoid are also numerous

FIG. 223.



Left orbit.

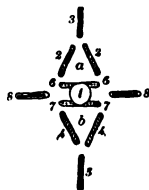
f frontal bone.
sp. m superior maxillary.
m malar.
l lachrymal.
e ethmoid.
s sphenoid.
p palatine.
1 optic foramen.
2 lachrymal groove.

cells containing air. The orbits, or sockets of the eyes, are two conical cavities at the upper part of the face, destined

for lodging the eyes: seven bones enter into the formation of the walls of each. The nasal cavities are formed by eleven bones. The bones seen inside the mouth chiefly constitute the bony palate, the fore-part formed by the superior maxillaries, the hind-part by the palatine bones: behind the palate are seen the internal and external pterygoid processes: in the mesian line of the anterior part of the maxillary palate is a small hole, the anterior palatine foramen: this is connected with both nares by a V-shaped canal (which is, however, closed by membrane).

122. A typical vertebra consists of a central body, centrum, and twelve processes, apophyses, variously denominated. From the upper part of the centrum rise two neurapophyses, which form an arch for enclosing the spinal cord (or "spinal marrow"): they are surmounted at the angle of their junction with each other by the neural spine. (The neurapophyses are usually termed laminæ, and their smaller anterior portions pedicles.) From the under side rise two hæmapophyses, surmounted by a hæmal spine: these are for enclosing a canal containing the chief blood-vessels, and sometimes, as in man, the digestive apparatus also. From the centrum also arise four transverse processes, the two diapophyses from the upper, and the two parapophyses from the lower part. There are also two transverse processes, the pleurapophyses, which surmount these, but are generally found attached to the parapophyses:

FIG. 224.

*Ideal typical vertebra.*

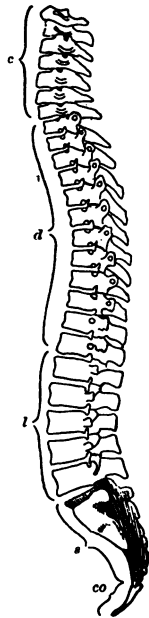
- 1 centrum.
- 2 neurapophyses.
- 3 neural spine.
- 4 hæmapophyses.
- 5 hæmal spine.
- 6 diapophyses.
- 7 parapophyses.
- 8 pleurapophyses.
- a neural canal and arch.
- b hæmal canal and arch.

from the pleurapophyses, on either side, there sometimes springs a diverging appendage. Various other minor processes are to be found. The vertebræ are variously modified, some elements being often absent. The bones of the head are by many considered to be composed of several

(probably *four*) modified vertebræ: in fish (which have small brains) we can trace a ring-like arrangement of the bones, which seems to bear out this view.

123. The vertebral column or axial skeleton of man consists of thirty-three vertebræ, of which twenty-four are slightly moveable, and the other nine coalesced into two compound bones. The column viewed laterally presents a double curve. A vertebra is an irregular bone, and each arises from seven (?) centres of ossification. The vertebræ are strapped together by several sets of ligaments, and for

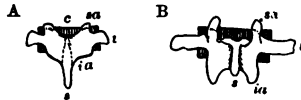
FIG. 225.



Vertebral column.

c cervical vertebræ. d dorsal. l lumbar.
s sacrum. co coccyx.

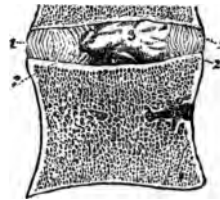
FIG. 226.



Dorsal surface of vertebra.

A dorsal. B lumbar. c centrum (shaded).
s neural spines. t transverse processes.
sa, ia superior and inferior articulating
processes.

FIG. 227.

Section of a vertebra. Showing osseous tissue
and intervertebral pad.

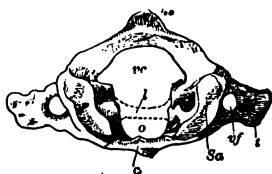
1, 2 fibrous portion. 3 pulpy portion.

the most part they are united to each other by pads of fibro-cartilage, which form rings round the edges, the central part of each pad being pulpy: the fibres are arranged in oblique rings, and interlace slightly: the pulpy tissue contains numerous cartilage corpuscles. The upper and under surfaces of the centra are nearly flat, both being slightly concave. The intervertebral discs permit of but

very slight motion to each individual vertebra, but of considerable motion to the whole; they also serve as a protection against shocks, which, if the column were solid, would travel upwards, and cause concussion of the brain from running, jumping, &c. Similarly, the pads of adipose tissue under the heels prevent jarring in walking, &c.; while, again, a person jumping from a height alights upon his toes, thus breaking the fall by interposing a kind of spring, formed by his bent limbs. The vertebræ are divided into five classes.

A. The seven *Cervical* are small, and have the transverse processes (par- and pleurapophyses) rudimentary and soldered together so as to form a hole on either side, through each of which pass a vertebral artery and vein. The spines have bifid extremities, excepting in the atlas, and the seventh vertebra (v. prominens). The two first are modified for articulation with the skull. The *atlas* (or first vertebra) has

FIG. 228.

*Atlas, from above and before.*

c centrum. *t* transverse process. *ns* neural spine. *sa* superior articulating surface for occipital condyles. *vf* vertebral foramen for vertebral artery. *l* ligament, in front of which a space *o* which receives the odontoid process of the axis, and behind it *cc* the vertebral canal for the spinal cord.

a very slender centrum, and presents two articular surfaces—glenoid cavities—upon which the occipital condyles rest.

FIG. 229.

*Axis.*

A lateral view. B seen in perspective from before.
c centrum. *t* transverse process. *vf* vertebral foramen. *f* notch for forming inter-vertebral foramen. *ns* neural spine. *sa*, *ia* superior and inferior articulating processes for adjoining vertebræ. *o* odontoid process. *o'*, *o''* its anterior and posterior articulating surfaces.

From the centrum of the *axis* (or second vertebra) rises a dentate or *odontoid* process, which is received by the atlas,

and which developmentally seems to belong to the centrum of the atlas. Around this pivot the skull and atlas move in rotatory movements of the head, whilst in upward and downward movements the condyles play upon the atlas.

FIG. 230.

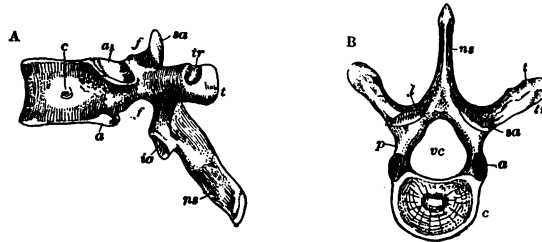


A cervical vertebra.

A lateral view. *B* seen in perspective from above and before.
c centrum. *t* transverse process, bifid at its extremity, and grooved superiorly for passage of the nerves. *ns* neural spine. *sa*, *ia* superior and inferior articulating surfaces. *v* vertebral foramen. *vc* vertebral canal.

B. Twelve Dorsal Vertebrae. These vary slightly in size, have stout parapophyses, and broad tile-like neurapophyses. The pleurapophyses are greatly developed forming the *costae* or *ribs* (F), twenty-four in number: each is a long, slender, curved, flattish bone, having a rounded head, which articulates by two facets with the body of its vertebra, and with the body of the vertebra above: the 1st, 10th, 11th, and 12th ribs have only one facet, and so articulate

FIG. 231.



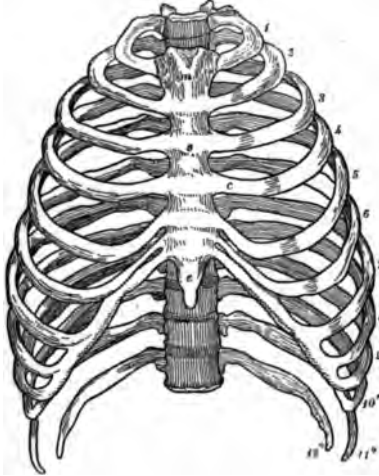
A dorsal vertebra.

A lateral view. *B* upper surface.
c centrum. *t* transverse process. *p* pedicle. *l* lamina. *ns* neural spine. *f, f* notches which form the intervertebral foramina. *sa*, *ia* superior and inferior articulating surfaces for adjoining vertebrae. *a*, *a* articular facets for heads of ribs. *tr* articulating surface for tubercle of rib. *vc* vertebral canal.

with their own vertebrae only. Thus the 1st vertebra has a facet and half, the following seven two half facets each, the 9th a half facet, and the last three a whole facet each. Near the head is a small tubercle which articulates with the transverse process of its vertebra (except the 11th and 12th

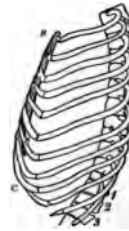
ribs, which want these articulations). The part between the head and tubercle is termed the neck. The ribs terminate hæmally in costal cartilages (undeveloped

FIG. 232.

*Bones of the thorax.*

1—7 vertebro-sternal ribs. 8'—10' vertebro-costal ribs. 11', 12' vertebral ribs. *s* sternum. *m* manubrial part. *e* ensiform cartilage. *c* a costal cartilage.

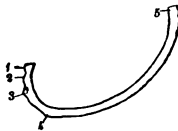
FIG. 233.

*Thorax, outer aspect.*

The left ribs only are shown. *s*, *s* sternum. *c* costal cartilages. 1, 2, 3 upper lumbar vertebrae.

hæmapophyses), which directly join the sternum in the upper seven ribs, hence called *true* or vertebro-sternal ribs, whilst the lower five are termed *false* ribs: the upper three false ribs, the vertebro-costal ribs, are joined together and to

FIG. 234.

*A rib (4th).*

1 head. 2 neck. 3 tubercle. 4 angle. 5 sternal end, attached to costal cartilage.

FIG. 235.

*A rib, from behind and above.*

uf, *lf*, *tf* upper, lower, and tubercular articulating facets. *a* angle of rib. *c* joined to costal cartilage.

the rib above by costal cartilages, that of each rib going to the one above; the two lowest, the floating or vertebral ribs, have the anterior ends free. The 8th and 9th are the

longest ribs, the others graduating either way. The 1st ribs are almost horizontal, the others becoming more and more sloping.

FIG. 236.



Articulation of a rib.

h head. *n* neck. *t* tubercle, *t* its non-articular and *t'* its articular portion.

FIG. 237.

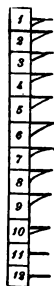


Articulation of rib with vertebra. Seen from behind.

h head. *n* neck. *t* tubercle. *a* angle.

The *sternum* or breast-bone (F. formed by coalesced hæmal spines) is a long flat bone, divided into three parts; (1) Manubrium, or pre-sternum (1 centre), a broad upper piece, to which the 1st rib is attached. It becomes joined to the mesosternum, the junction usually being effected by synarthrosis, or diarthrosis (there is rarely a cavity); so the manubrium is by many reckoned as a separate bone; (2) Gladiolus, or meso-sternum (consisting of four coalesced

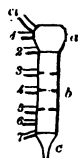
FIG. 238.



Plan of the attachment of the ribs.

The numbers indicate those of the dorsal vertebrae, the horizontal lines the heads of the ribs, the oblique lines the tubercular processes.

FIG. 239.



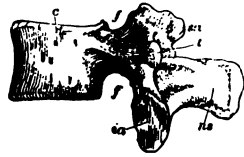
Theoretical diagram of the sternum. Showing its anchyloses and junctions with the seven true ribs.

a manubrium. *b* gladiolus. *c* ensiform cartilage. *cl* clavicle.

centra), forming the main portion, and having the next six ribs on either side attached to it; (3) the xiphoid or ensiform cartilage, a narrow terminal piece of cartilage. The sternum, ribs, and dorsal vertebræ form the thoracic cage.

C. The five *Lumbar* vertebræ are the largest, have short parapophyses and broad spines, but are devoid of ribs.

FIG. 240.



A lumbar vertebra. Lateral view.

c centrum. *t* transverse process. *ns* neural spine. *f, f* lateral notches for the foramen. *sa, ia* superior and inferior articulating surfaces.

D. The five *sacral* vertebræ are soldered together into one flattish triangular bone (with the apex downwards), the *sacrum*: both its anterior and posterior surfaces are

FIG. 241.



The sacrum.

A from before. B from above. C from behind.

a central articulating surface. *a* articular processes. *s* spinous processes. *f* foramina. *cc* vertebral canal. *i, i* surface which articulates with ilium.

perforated by four pairs of holes for the transmission of nerves.

E. The four *coccygeal* vertebræ are extremely small, and soldered together into one bone, the *coccyx*. In man the

FIG. 242.



The coccyx from before. (Seen to consist of four bones.)

1 articulating surface.
2 articulating cornua.
3 transverse processes.

coccyx is very rudimentary: the coccygeal vertebræ form the tail of animals.

124. The bones of the limbs, forming the appendicular skeleton, are capable of division into two distinct sets; (A) the two fore-limbs or arms, joined to the trunk by the

scapular arch; (B) the two hind-limbs or legs, joined to the trunk by the pelvic arch.

125. The scapular arch, pectoral arch, or shoulder-girdle, consists of two bones on either side; (1) the *scapula* or

FIG. 243.

*The shoulder-joint from before.*

- 1 manubrium.
- 2 clavicle.
- 3 acromion process of the scapula.
- 4 coracoid process.
- 5 head of the humerus.

shoulder-bone (F) is a large flat bone: on its dorsal surface is a ridge, ending at the upper outer corner in an expansion, called the acromion process, just beneath which is a shallow glenoid cavity. The *coracoid process* (which forms a separate bone in most animals) is attached just in front of the glenoid cavity to the anterior surface of the scapula. A

FIG. 244.

*Dorsal surface of right scapula.*

- c coracoid. ac acromion process. s spine.
- g glenoid articulating surface. s, s supra-spinous fossa.

FIG. 245.

*Outer edge of scapula.*

- 1 acromion process. 1' spine. 2 coracoid process. 3 glenoid cavity for humerus.

FIG. 246.

*Superior view of left clavicle.*

- 1 articulates with the sternum, 2 with the acromion process.

prominent ridge, "the spine," runs across the dorsal surface; (2) the *clavicle* or collar-bone (L) is a slender, slightly curved bone, articulating at one end with the upper corner of the manubrium sterni, at the other with the acromion

process of the scapula. It serves to keep the shoulders apart.

126. Each arm consists of three portions.

I. The *humerus* (L) or bone of the upper arm, consists of a head, neck, shaft, and condyles. Its head is received into

FIG. 247.



Front view of right humerus.

h head.

g, t greater and lesser tuberosities.

ic, ec internal and external condyles.

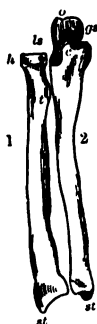
t trochlea.

c capitellum.

the scapular glenoid cavity, forming a ball-and-socket joint. Its lower end is expanded into two condyles.

II. The fore-arm consists of two bones, the *radius* (L) and the *ulna* (L) nearly parallel to each other, both articu-

FIG. 248.



Front view of right fore-arm.

1 radius.

h head.

t tubercle.

st styloid process.

2 ulna.

o olecranon process.

gs, ls greater and lesser sigmoid processes.

c coronoid process.

st styloid process.

lated to the humerus by a hinge-joint,—the elbow-joint. The flexion and extension of the arm is chiefly effected through the ulna, at the upper end of which is the olecranon process, preventing too great extension of the arm (i. e. beyond the straight line) : a similar provision occurs in all other hinge-joints. In front of this process is the articulating cavity,

the sigmoid notch, for the reception of the one condyle of the humerus. The radius is a stouter and somewhat shorter bone. Its head is bound to that of the ulna by an annular

FIG. 249.



*Bones of the right arm in pronation and supination. (After Beau-
nis and Bouchard.)*

*a, a axis of rotation. h humerus.
u, u ulna. r, r the radius in
pronation. r' r' in supina-
tion.*

or orbicular ligament; but the lower part revolves upon the ulna in rotation of the hand. In supination, when the palm of the hand is directed forwards, the radius is outermost; in pronation, or direction of the palm backwards, the radius rotates upon the ulna in such a manner that its *lower* end becomes innermost. The radius is on the same side as the thumb.

III. The *hand* is divided into three portions.

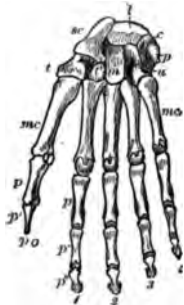
A. The *carpus*, or wrist, consists of eight small bones, (S) the *carpals*, arranged in two rows. In the first, or proximal row (that nearest the body) are four bones, beginning at the radial or thumb side, these are: 1, scaphoides; 2, lunare; 3, cuneiforme; 4, pisiforme. 1 and 2 are articulated with the radius, 3 with the ulna, 4 to the posterior surface of 3. The second or distal row also consists of four bones, which, in the same order, are:

5, Trapezium; 6, trapezoides; 7, magnum; 8, unciform.

B. The *metacarpus* consists of five bones (L) articulated

proximally to the distal carpals. They underlie the palm of the hand.

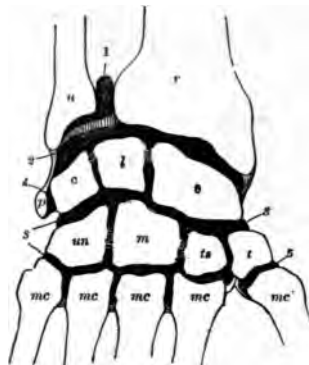
FIG. 250.



Anterior surface of right hand.

s scaphoid. l semilunar. c cuneiform. p pisiform. t trapezium. tr trapezoides. m magnum. u unciform. mc metacarpals. p p' p'' 1st, 2nd, and 3rd rows of phalanges. p pollex. 1, 2, 3, 4 the four fingers.

FIG. 251.



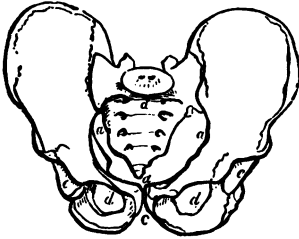
Dorsal surface of right carpus. Showing the synovial membranes, and the articulations.

r radius. u ulna or cubitus. s scaphoides. l lunare. c cuneiform. p pisiform. t trapezium. tr trapezoides. m magnum. u unciform. mc metacarpals. (mc' metacarpal of pollex.) 1, 2, 3, 4, 5 the five synovial membranes.

C. The five *digits* consisting of fourteen small bones—the *phalanges* (L)—of which two belong to the *pollex* or *thumb*, and three to each of the four *fingers*, thus forming three rows, the proximal, middle, and distal (the thumb of two—proximal, and distal [median developmentally]). The thumb, together with the metacarpal attached, is opposable to the rest of the hand. The metacarpo-phalangeal articulations, as also the interphalangeal ones, are popularly termed 'knuckles.'

127. The pelvic arch consists of two great compound bones, the *ossa innominata*, or haunch-bones (F), which, together with the sacrum and coccyx, constitute a kind of large basin, the *pelvis*, open above and below, and sloping downwards and backwards. The upper edge is termed the brim; the lower opening—the outlet; the lower part of the pelvis just above the outlet—the true pelvis. The great strength of the pelvic region gives stability to the body, being just beneath the centre of gravity. The true pelvis and outlet are much larger in the female than in the male (on account of parturition), and the pelvis is rather differently

FIG. 252.



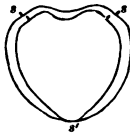
Male pelvis. (Agassiz and Gould, after South.)
a, a, a, a brim of true pelvis. *c* symphysis pubis. *d* obturator foramen. *e* acetabulum.

FIG. 253.



Female pelvis. (Agassiz and Gould, after South.)
 Letters as in preceding figure.

FIG. 254.



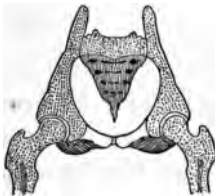
Brim of pelvis. The inner line male, the outer line female.
s, s sacro-iliac articulations. *s'* symphysis pubis.

FIG. 255.



Diagram representing attachment of sacrum and ilium.

FIG. 256.



Section of pelvis. Showing the suspension of the sacrum.

FIG. 257.



Section of pelvis.
a, a line of fulcrum (through acetabulum).
b, b line of power (symphysis pubis).
c, c line of weight (sacro-iliac joint).
d, d line of sacral projection.
a, e, f sacro-vertebral angle. (117° in the male, 130° in the female.)

shaped; amongst other things, the ilia are broader, and the hips, therefore, are more prominent; the pelvic bones in the female are also slightly moveable. The pelvis also serves to protect some of the viscera, e. g. the bladder. Each os innominatum consists of three bones, which are anchylosed in the adult. (1) The *ilium*, or hip-bone, a

FIG. 258.



Left innominate bone, outer side.
i ilium. *is* ischium. *p* pubis. *a* acetabulum. *o* obturator foramen.

FIG. 259.



Left os innominatum, inner side.
i ilium. *c*, *c* its crest. *is* ischium. *p* pubis. *s* symphysis pubis. *o* obturator foramen. *a* auricular surface for articulation with sacrum. *l* surface of ligamentous attachment.

broad, flat bone, attached behind to the sacrum. (2) The *ischium* attached to the lower part of the ilium, and to the pubis. (3) The *pubis*, attached to both these bones, and in front by the symphysis pubis,—a synchondrosis, or cartilaginous union, to its fellow of the opposite side. There is a

FIG. 260.



Theoretical diagram of an os innominatum, as though transparent.

i ilium.
i' attachment to sacrum.
is ischium.
p pubis.
pu symphysis pubis.
1 acetabulum.
2 obturator foramen.

large ovoid hole in each os innominatum, between the ischium and pubes—the *obturator foramen*, partly closed by ligament, and which gives passage to blood-vessels and nerves; above and behind it is a cup-shaped cavity, the *acetabulum*, in the formation of which all three bones participate.

128. The leg consists of three parts.

I. The *femur* or thigh-bone (L) is homologous to the humerus, and consists of like parts. The femur of man is relatively longer than that of any animal, and is actually one of the longest. Its head is received by the acetabulum, forming a ball and socket joint—the hip-joint. At the

FIG. 261.

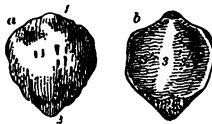


Right femur from before.

h head. *n* neck. *gt*, *lt* greater and lesser trochanters. *s* shaft. *ic*, *ec* internal and external condyles.

junction of the neck and shaft are two projections for muscular attachment, a very large external one—the greater trochanter, and a small posterior one—the lesser trochanter. The two condyles articulate with the tibia by a hinge-joint, —the knee-joint, in which the fibula does not take part. In

FIG. 262.



Right patella.

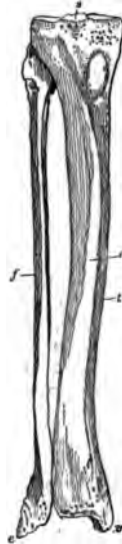
a anterior surface. *b* posterior surface.
1 base. 2 apex. 3 articulating surface. 3' applied to inner, and 3'' to outer femoral condyle.

front of the knee-joint is a rather small, flattish, sub-triangular bone, the *patella*, or knee-cap, which is of sesamoidal origin, though its invariable presence and its importance might justly cause it to be considered as a true skeletal bone.

II. The leg proper contains two parallel bones, the *tibia*

and *fibula*. The tibia, or 'shin-bone' is the inner, and by much the larger. The fibula is very slender, is attached

FIG. 263.



Right tibia and fibula from before.

t tibia. *f* fibula. *c* crest of tibia ('shin'). *s* spinous process. *i* internal malleolus.
e external malleolus.

to the tibia both above and below, and assists it slightly in the formation of the ankle-joint with the foot.

III. The foot consists of three parts.

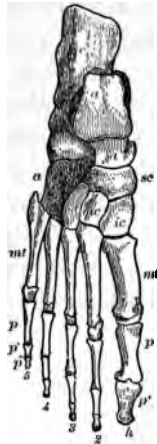
A. The *tarsus* consists of seven bones, also arranged in two rows. The first row consists of three bones arranged irregularly: 1, astragalus; 2, os calcis, os calcaneum, or heel-bone; 3, scaphoid bone or os naviculare. The os astragalus articulates above with the tibia and fibula, principally the former; below it rests upon the os calcaneum, which forms the whole of the heel. The scaphoid bone is on the inner side, being in front of the calcis; it is attached to 1 and 2. The second row consists of four bones, which (going from within outwards) are:

4. The internal, 5 middle, and 6 external cuneiform bones, also termed the ento-, meso-, and ecto-cuneiforme bones; 7, the os cuboides, or cuboid bone.

4, 5 and 6 articulate with 3, 7 with 2 (and 3 laterally). In front they articulate with the metatarsus.

B. The *metatarsus* consists of five bones, which articulate anteriorly with the toes.

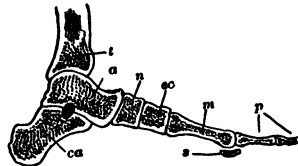
FIG. 264.



Upper surface of foot.

a, a astragalus. c os calcis. sc scaphoid. ic, mc, ec internal, middle, and external cuneiform. cu cuboid. mt metatarsals. p, p', p'' 1st, 2nd, and 3rd rows of phalanges. h hallux. 2, 3, 4, 5 the other four toes.

FIG. 265.



Section of foot and ankle-joint.

t tibia. ca calcaneum. a astragalus. n navicular. ec ento-cuneiforme. m metatarsal. p phalanges, and s a sesamoid bone of the hallux.

C. The five *digits* or toes consist of fourteen *phalanges*. Each has three (proximal, median, and distal) except the large inner toe, the *hallux*, or great toe, which has only two (proximal, and distal [median developmentally]).

129. Table of homologues or correspondences.

Scapula	=	Ilium.
(Coracoid)	=	Ischium.
Clavicle	=	Pubis.
Humerus	=	Femur.
Radius	=	Tibia.
Ulna	=	Fibula.
Carpus	=	Tarsus.
Metacarpus	=	Metatarsus.
Pollex	=	Hallux.
Finger-digits	=	Toe-digits.
Phalanges	=	Phalanges.

130. Besides the bones of the true or hæmal skeleton,

there are in the body several *sesamoid* bones, which arise from intra-tendineous ossification, and are found embedded in various tendons, and playing upon cartilaginous facets of bones. Such bones are the patella, and the two bones situate beneath the basal joint of each thumb, and of each great toe. Beside these nine, there are a variable number of others (usually five or more) in various places, sometimes beneath the basal joints of the fingers. Small sesamoidal bones are often developed by labour, to which indeed seems due the original development of all the sesamoidal bones. The pisiform bone is by some considered as belonging to this class; but developmentally it is possible that all the carpals and tarsals had originally a kind of sesamoidal origin, whilst the metacarpals and metatarsals should be considered as a row of phalanges, and as belonging to the digits.

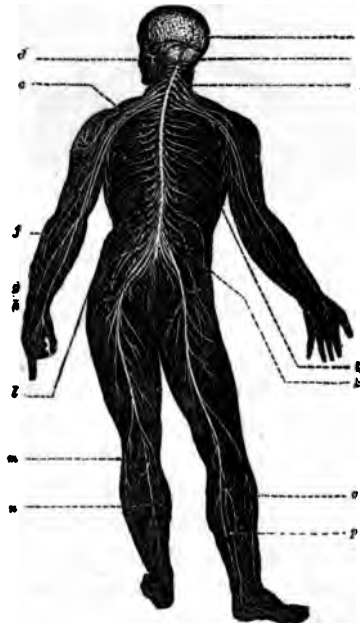
CHAPTER VI.

THE NERVOUS SYSTEM.

131. The nervous system is double, and consists of (1) the *cerebro-spinal* system, which has control over the motor and sensory apparatus, and body generally, and (2) the *sympathetic* system, which has control over the organic functions: both are intimately connected.

132. The cerebro-spinal system consists of a cerebro-

FIG. 266.



Nervous system.

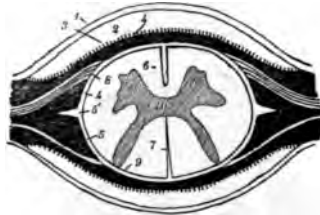
a cerebrum. b cerebellum. c spinal cord. d facial nerves. e brachial nerves. f median n. g ulnar n. h internal cutaneous n. i intercostal nerves. k lumbar nerves. l sciatic plexus. m, o external peroneal n. n tibial nerves. p external saphene n.

spinal or medullo-encephalic *axis*, and numerous pairs of *nerves* connected with the axis.

133. The axis itself consists of two portions, the *brain* and *spinal cord*. The axis contains a cavity of extremely varying shape and dimension in the different parts. The axis has a delicate epithelial layer, supported by a thin

layer of connective-tissue, together constituting the *ependyma*, which lines the central cavity, and the epithelial cells of which are mostly ciliated. The nervous matter consists of grey and white tissue. The grey tissue consists mostly of corpuscles with their prolongations and small fibres, and is more vascular than the white tissue, which contains no corpuscles. The blood-vessels, which are very minute, are derived from the pia mater, and only pass a little way inwards from the surface. The cerebro-spinal axis is lodged in the cranial cavity and spinal canal. It is invested by three membranes, or *meninges*.

FIG. 267.



Transverse section of spinal cord and its membranes.

1 dura mater. 2 arachnoid cavity. 3 arachnoid membrane. 4, 4 sub-arachnoid space.
5 pia mater. 5' denticulate membrane. 6, 7 anterior and posterior median fissures.
8, 9 anterior and posterior nerve roots. 10 grey matter of cord.

1. The *pia mater*, which is innermost, consists of highly-vascular connective-tissue, and immediately invests the whole axis, sending double folds down into the sulci, and single processes into the two cord fissures. In the spinal region, where it is firmer, it sends out (A) the ligamentum denticulatum, a serrated fibrous band, which runs along either side; its teeth (about twenty-two) pass between the nerve-roots alternately (one between almost every pair), and are attached to and become structurally continuous with the dura mater; it terminates below in a central process,—filum terminale: (B) an incomplete posterior median band,—septum posticum, which joins it to the arachnoid.

2. The *arachnoid* membrane, a modified *serous* membrane, interposed between the pia mater and dura mater, and generally considered as forming a closed sac, which invests the whole axis. The inner layer is attached to the pia mater;—it does not descend into the sulci, and is but

loosely attached in the spinal region, and in parts of the brain, thereby leaving an interspace, the sub-arachnoid space, which is filled with the cephalo-spinal or cephalo-rachidian fluid, secreted by the pia-mater. The outer layer is reduced to a single layer of cells which furnishes the dura mater with an epithelium : more probably this epithelium does not belong to the arachnoid. The fluid enclosed in the arachnoid sac, or subdural space, is the arachnoid fluid, and is secreted by the arachnoid membrane itself.

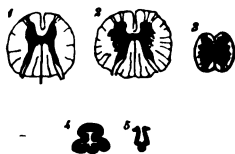
3. The *dura mater* consists of dense white-fibrous tissue, and has an epithelium. It serves for periosteum to the inside of the cranium, but in the cord forms a sheath, theca, separated by loose fatty areolar tissue from the vertebral periosteum. It is very indistinctly divided into two layers, the inner of which sends down three processes. (A) A longitudinal process, the *falx cerebri*, which incompletely separates the cerebral hemispheres, is continuous with the crista galli before, and with (B) the *falx cerebelli* behind : at its junction with the latter is a transverse ridge (C) the *tentorium cerebelli* separating the cerebrum and cerebellum. In the cranium the two layers are separated in several situations, forming fifteen irregular venous cavities, termed sinuses. Embedded in the dura mater, under and near the falx cerebri, are minute granular pulpy bodies, the glands of Pacchioni, which appear externally as small elevations : a few are also found in the pia mater and elsewhere ; each consists of a mass of connective-tissue cells.

The brain and spinal cord are thus protected from injury by a bony case, whilst the two fluids diffuse any slight pressure exerted ; the pouches at the nerve-roots, as well as the great activity of absorption by (and possibly the peculiar construction of) the copious lymphatic supply also aid in diffusing pressure.

134. The *spinal cord* (*medulla spinalis*), which is nearly cylindrical (tapering *slightly*), is about 18—20 inches long, commencing at the foramen magnum, and terminating (in a tapering cone) with the 1st lumbar vertebra ; weight $1\frac{1}{2}$ oz. (1—1 $\frac{3}{4}$). It undergoes two enlargements, an upper cervical (3rd C, 1st D, vertebræ) and a lower lumbar (at about

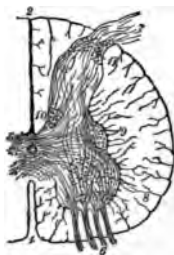
the last dorsal vertebra); the cord at these parts is rather elliptical laterally. Down the anterior surface of the cord runs the anterior fissure, which is broader, but not so deep as the posterior fissure of the hinder surface. Each half of the cord is divided into three columns by the anterior—and posterior—lateral fissures, both unimportant except as boundary-lines. A minute tube, the central canal (diam. $\frac{1}{16}$ in.), lined with ependyma, passes down the centre of the cord. The white matter is outside the grey, which is in

FIG. 268.



Transverse sections of the spinal cord.
1 at 2nd cervical. 2 at 6th cervical. 3 at 2nd coccygeal nerves. 4 shape of central canal near lower extremity. 5 its opening there.

FIG. 269.



Transverse section of half the spinal cord at the lumbar enlargement.

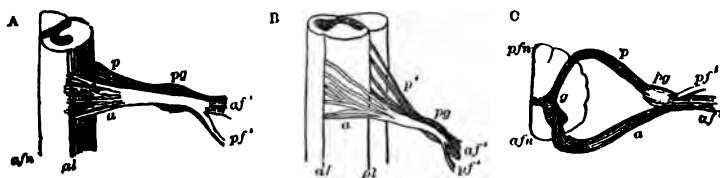
- 1 anterior fissure. 2 posterior fissure.
- 3 central canal. 4 anterior commissure.
- 5 posterior commissure. 6 fasciculi of anterior root. 7 posterior root. The cells are chiefly gathered into groups.
- 8 anterior groups. 9 tractus intermedio-lateralis. 10 posterior vesicular column ('sympathetic tract').
- 11 substantia gelatinosa. 12 connective-tissue processes.

the form of two crescents connected by a grey commissure, in the centre of which is the central canal: the white matter of the two halves is united by an anterior white commissure in front of the grey one. Each crescent has a narrow posterior cornu, which runs to the surface, and a short but broader anterior one, which stops short, but sends out several filamentary bundles to the surface.

135. From the spinal cord spring out thirty-one pairs of spinal nerves, which pass out between the vertebræ through the intervertebral foramina. Each nerve arises by two roots, (1) *anterior* branched, one springing from anterior lateral fissure; (2) *posterior*, from posterior lateral fissure. Both roots, in passing through the foramina, unite together. The roots are at first invested with pia mater, and then with dura

mater, both these coverings passing into the neurilemma; the arachnoid membrane also sends out a very short prolongation around the root. Just before conjoining, the posterior root presents a small ganglionic enlargement, connected with the sympathetic system, and almost immediately after their conjunction, the nerve bifurcates, forming a small posterior and a large anterior branch. The anterior branches often join together to form a *plexus*, in which there is no real anastomosing network, but simply an apposition of fibres. Of the thirty-one pairs of spinal nerves, most are named after the vertebræ above them: there are eight cervical, twelve dorsal, five lumbar, five sacral, and

FIG. 270.



Spinal nerve-roots.

A seen from before. B from the side. C from above.
g grey matter of cord. *am*, *pm* anterior and posterior median fissures. *al*, *pl* anterior and posterior lateral fissures. *a*, *p* anterior and posterior nerve-roots. *pg* ganglion of posterior root. *af*, *pf* larger anterior and smaller posterior nerve-fillets.

one coccygeal pairs; the first passing out above the atlas, then comes a regular series, the last but one passing out above the coccyx, the last behind it. The nerve-plexuses, four in number, are thus formed: Cervical by C, 1 2 3 4 (=cervical 1st, 2nd, &c.), Brachial, C, 5 6 7 8, D 1; Lumbar, L, 1 2 3 4; Sacral, 1 5, S, 1 2 3 and part of 4. They are formed from the greater part of the anterior branches, receiving small communications from other nerves also. The *phrenic* nerve is chiefly derived from C 4. The nerve-roots slope obliquely downwards before passing out of the canal, the lower much more so than the upper ones. The elongated roots which occupy the canal below the termination of the cord form a flat bundle called the *cauda equina*, in the centre of which is the *filum terminale*, containing a filamentary prolongation of the cord.

136. The *brain* or *encephalon* consists of the cerebrum,

cerebellum, isthmus, and medulla oblongata—all intimately connected with one another. The whole brain is enclosed within the cranial cavity. The average weight of the brain in man (Europeans) is 49 oz. (50½), in woman 44; varying between 64 and 31 (31—56 in woman, 34—64 in

FIG. 271.

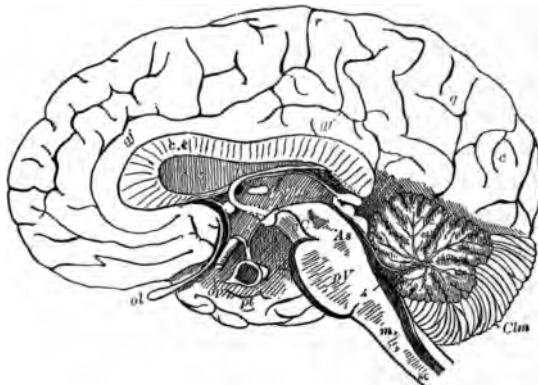
*The encephalon.*

f, p, o, t frontal, parietal, occipital, and temporal lobes of cerebrum. *c* cerebellum. *p* pons Varolii. *m* medulla oblongata. *s* spinal cord. *at* atlas. *ax* axis.

man); of which 49, the cerebrum weighs 42, cerebellum 5, isthmus 1, pons and medulla 1. The usual percentage between certain weights is

	oz.		oz.		oz.		oz.
Man	34	·08	45	·75	55	·17	62
Woman	36	·55	45	·45	55		

FIG. 272.

*Antero-posterior section of encephalon.*

g gyrus fornicatus. *cc* corpus callosum. *s* septum lucidum. *5* fifth ventricle. *f* fornix. *3* third ventricle. *ol* olfactory lobe. *op* optic nerve. *pt* pituitary body. *cm* corpus mammillare. *cO* crux cerebri. *As* Aqueduct of Sylvius. *pV* pons Varolii. *4* fourth ventricle. *m* medulla oblongata. *sc* spinal cord. *cim* cerebellum. *c* cuneate lobe. *q* quadrate lobe.

In the American Civil War the whites averaged 52 oz., the negroes 47, the mulattoes even *less* than the negroes if black blood predominated. The brains of clever people are usually somewhat heavier than those of ignorant ones; 50½ is probably about the average for males of the English middle class. The encephalon occupies about 80 cub. in. (in whites).

137. The *medulla oblongata* is continuous with the spinal cord, of which it seems to be a bulbous enlargement. It is the medium of connexion between the rest of the brain and the cord, but is also an independent centre. It is divided into two halves by the anterior and posterior fissures, continuous with those of the cord. Each half consists of

FIG. 273.



Anterior view of the medulla oblongata and pons.

- a* anterior pyramid.
- b* its decussating fibres.
- c* olivary bodies.
- d* arciform fibres.
- e* fibres going from the anterior columns to *f* the restiform bodies.
- g* anterior columns of spinal cord.
- h* lateral columns.
- i* pons Varolii; upon its upper surface are seen *5*, *5* the roots of the fifth pair of nerves.

four columns or tracts, which, proceeding backwards, are (1) anterior pyramids, (2) lateral tract, (3) restiform body, (4) posterior pyramids.

The *anterior pyramid* derives its fibres mostly from the *antero-lateral* (anterior part of the lateral) column of spine: these push to the anterior surface, and decussate with the corresponding fibres of the opposite side, forming the decussation of the pyramids, a few fibres from the postero-lateral and posterior columns also perhaps aiding, and some fibres from the anterior columns which do not decussate. The fibres mostly go above to the corpus striatum and

cerebrum, but some also to the restiform bodies and cerebellum.

At the top, between the anterior pyramid and lateral tract, is an ovoid prominence, the *olivary body*, a ganglionic mass, which is surrounded by fibres of the anterior columns, and which sends up a fasciculus or fillet of fibres to the tubercula quadrigemina and C^{llm}. (cerebellum). The *lateral tract* is derived below from the *lateral column* of the cord, and passes above into the fasciculi teretes, and so to the C^m. (cerebrum), a few fibres also going to the C^{llm}.

The *restiform body* springs from the *posterior* chiefly, and from the postero-lateral columns. It is joined by fibres from the anterior pyramids and lateral tracts. Above, it is connected with the C^{llm}. only, forming the inferior cerebellar

FIG. 274.



Section of the medulla oblongata and neighbouring parts. (Showing the direction of columns. Arnold.)

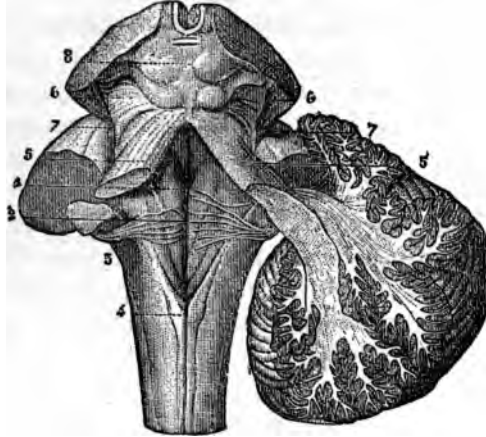
a part of anterior columns going to olivary fasciculus. b anterior decussating fibres. c olivary fasciculus. d olivary body. e restiform body. f pons. g testes. h part of olivary fasciculus which goes to the cerebral peduncle. i part which goes to the quadrigemina. m, n transverse fibres of pons. n inferior cerebellar peduncle, continued at q, q into the cerebellar laminae. o septal medullary fibres. r, r superior cerebellar peduncle. t fasciculi teretes. u optic thalamus. v corpus albicans.

peduncles, which do not enter the pons. All fibres which come from the cord and are connected with the C^{llm}. are found in the restiform body.

The *posterior pyramids* are two small tracts derived from the *postero-lateral* chiefly, and posterior columns of the cord. They decussate higher up than the anterior columns. The fibres go above to the optic thalami and C^m. The posterior pyramids bound the posterior fissure, which at the top widens, the interspace being partly enclosed by two folds of extremely delicate membrane, the *ligulæ*, continuous with

the ependyma, but leaving an opening, the foramen of Magendie, by which the 4th ventricle communicates with the sub-arachnoid space: this groove or fissure leads into the

FIG. 275.



Floor of the fourth ventricle with neighbouring parts. (Partly dissected. After Hirschfeld and Leveillé.)

- 1 median groove with the fasciculi teretes, one on either side. 2 the same, where the auditory nerve-roots emerge. 3 inferior cerebellar peduncle (restiform body). 4 posterior pyramid. 5 superior peduncle. 6 fillet going to crura cerebri. 7 lateral grooves of crura. 8 corpora quadrigemina.

FIG. 276.



Theoretical diagram of the medulla oblongata.

- 1 anterior column. 2 antero-lateral column. 3 postero-lateral column. 4 posterior column. *a* antero-lateral fissure. *b* postero-lateral fissure. 5 anterior pyramid. 6 olivary body. 7 lateral medullary column. 8 restiform body. 9 posterior pyramid.

FIG. 277.



Diagram illustrating the decussation of the anterior pyramids.

- 1 the anterior pyramids. 2 lateral column. 3 restiform body. 4 posterior pyramids. 5 olivary body. *ac* anterior spinal column. *lc* lateral column. *pc* posterior column. *r, r* fibres going to the restiform body.

lower part of the 4th ventricle, the opening being in its floor. The central canal also possesses an opening at the bottom of the spinal cord.

Joining the ant. pyramids and restiform bodies are certain *arciform* fibres, which seem to come down the one column, and form a loop across, passing up the other. There is both an external and an internal set: they probably arise from medullary nuclei of ganglionic substance, those of the external set being in the restiform bodies.

Looking at the spinal cord, the anterior columns (the fibres of which, mostly at least, decussate throughout the cord) pass above (1) into the ant. pyramids, not decussating, (2) embracing the olivary body, pass up with its fibres to the c. quadr^a and C^m and (3) deep fibres, which go to the restiform body (and C^l^{lm}). The fibres of the lateral column mostly (1) decussate in ant. pyramids, (2) some fibres go to the C^m (3), others, superior and deep, to the restiform bodies. Those of the posterior columns (1) to the C^m. (2) to the restiform bodies.

FIG. 278.



Theoretical section of half the spinal cord, showing to what parts of the medulla oblongata its fibres run.

1, 1' to anterior pyramids (1' do not decussate). 2 to lateral columns. 3 to restiform body. 4 to posterior pyramids. a antero-lateral fissure. b postero-lateral fissure.

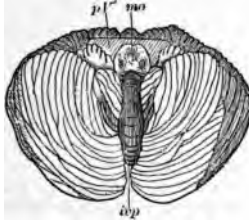
The ganglionic bodies of the med. oblongata are the two olivary bodies, which are connected with and are supposed to have control over the hypo-glossal and part of the glosso-pharyngeal nerves: the two restiform ganglia, which control the pneumogastrics and the other part of the glosso-pharyngeal nerves: the two ganglia of the post-pyramids which are very small, and supposed to control the auditory nerve. The grey matter of the medulla is more or less mixed throughout with the white, the chief bodies of grey (or nearly pure grey) matter being these ganglia.

138. As the fibres of the med. oblongata pass upwards, they are surrounded by the cerebellum (behind), and the pons Varolii (on the other sides); the medullary substance within is termed the tuber annulare.

139. The *cerebellum* is a bilobular mass, whose surface is divided by transverse grooves into numerous, nearly parallel

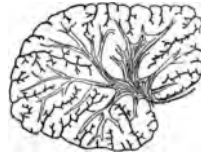
laminae. The white matter (which is within) presents a peculiar appearance termed the arbor vitæ. The two hemispheres, or lateral lobes of the C^{llm} , are united by a small vertical ridge (median lobe of vertebrates generally) the upper surface of which is termed the superior, and the lower the inferior vermiform process. The hemispheres are partly

FIG. 279.



Under surface of the cerebellum.
no section of medulla oblongata, pV pons
Varolii cut away. ivp inferior vermi-
form process ('central lobe').

FIG. 280.



A section of cerebellum, showing the sulci
and (larger branches of) arbor vitæ.

separated by the falx C^{lli} . The fissure is termed the vallecula. Each hemisphere contains in its centre a nucleus of grey matter, the corpus dentatum, and each may be divided into eight lobes by certain fissures slightly deeper than the rest:—central, sup^r ant^r or quadrate, sup^r post^r, inf^r post^r, slender, biventral, amygdala, and sub-peduncular or flocculus.

FIG. 281.



Another section of cerebellum through a
hemisphere.
cd corpus dentatum. pV pons Varolii.
on olivary nucleus.

FIG. 282.



A group of laminae, showing the grey and
white matter more clearly.

From the C^{llm} run three pairs of processes—peduncles, (1) the inferior in direct continuation with the restiform bodies, and so ultimately with the cord; (2) the median going to form the pons Varolii; (3) the superior going to the tubercula quadr^a, optic thalami, and C^{m} .

140. The *pons Varolii* appears as a band of transverse

fibres running around the longitudinal ones: it serves as a commissure between the two lobes of the C^{lm} ; so the pons is to the C^{lm} what the corpus callosum is to the C^m . It really consists of two bands, (1) an external one, some fibres of which pass completely round to the opposite side, others dip down at the middle line (where a slight furrow is visible) passing in, some of these forming a mesial raphe, the others

FIG. 283.



Section of the pons Varolii.

c the central lobe, and A, a the hemispheres of the cerebellum (left white). The dots represent the section of the longitudinal fibres passing up from the medulla. The lines represent the fibres of the pons itself.

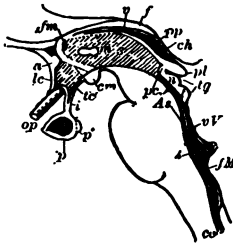
being lost among the longitudinal ones, but probably also returning (to the central lobe); (2) an internal one which separates the longitudinal fibres into two bundles—anterior and posterior—and returns, after forming a circuit. The pons is perhaps equally connected with the central part as with the hemispheres of the C^{lm} ; the restiform bodies and the superior processes are connected with the hemispheres, the fibres from the corpora dentata joining the superior processes.

141. The superior processes, or processus cerebelli ad testes, converge and meet at the testes, and are united together by a delicate layer, the valve of Vieussens; these together form the roof of the 4th ventricle, the C^{lm} the back, whilst in front, it is open above, passing into the 3rd ventricle; below this are the longitudinal fibres going to the C^m , and which are termed from this aspect the fasciculi teretes; below, the 4th ventricle is continuous with the central canal of the cord. The 3rd and 4th ventricles are connected by a narrow *iter*—the aqueduct of Sylvius—which runs beneath the c. quadrat-

142. The corpora quadrigemina, or tubercula quadrigemina are four slight protuberances (the optic lobes of vertebrates) which project upwards; the anterior pair (also the larger) are the nates, the posterior pair the testes. In front of them is a small prominence, the pineal gland.

143. The walls of the 3rd ventricle form the *isthmus*, which consists chiefly of fibres passing to (and from) the C^m . The roof is formed by the velum interpositum, composed of a reduplication of the pia mater, and its attached arachnoid, and of ependyma. The edges of the pia mater are very vascular, villous and fringed, and form the choroid plexuses,

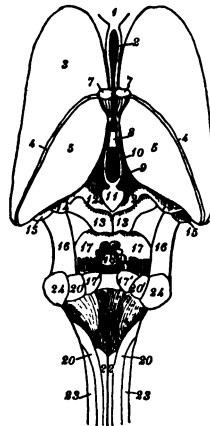
FIG. 284.



Antero-posterior section of mesencephalon.

fm foramen of Munro. *a* anterior commissure. *lc* lamina cinerea. *op* optic nerve. *p* pituitary body. *p* anterior, and *p'* posterior lobe. *i* infundibulum. *tc* tuber cinereum. *cm* corpus mammillare. *cc* central canal. *fm* foramen of Magendie. *4* fourth ventricle. *vV* valve of Vieussens. *Aa* Aqueduct of Sylvius. *tg* tubercula quadrigemina. *t* testes. *n* nates. *pc* posterior commissure. *pl* pineal gland. *ch* choroid plexus. *pp* pineal peduncle. *f* fornix. *v* velum. *3* third ventricle. *m* middle commissure.

FIG. 285.



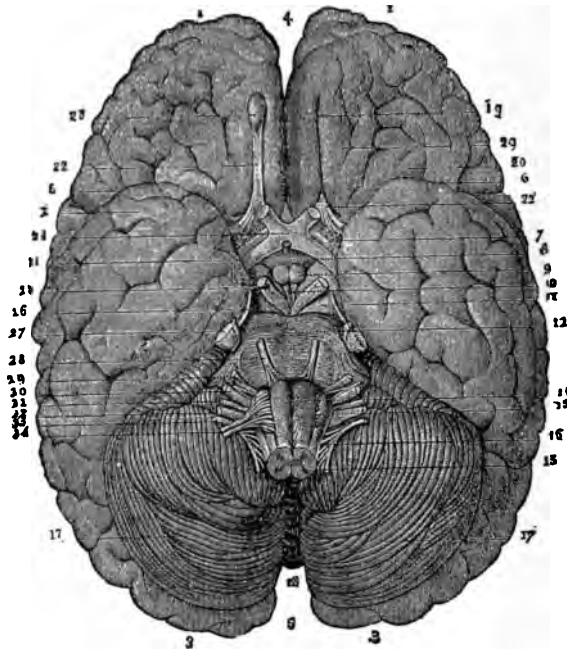
Central portion of brain, from above and behind.

- 1 septum lucidum. 2 fifth ventricle.
- 3 corpora striata. 4 tænia semicircularis. 5 optic thalami. 6 pulvinar.
- 7 cut crura of fornix. 8, 9 middle and posterior commissures of third ventricle, which is seen between 10, 10 the peduncles of 11 the pineal gland.
- 12 the nates. 13 testes. 14, 15 corpus geniculatum internum and externum.
- 16 crura cerebri. 17 superior cerebellar peduncle, at 17' cut across.
- 18 valve of Vieussens. 19 fourth ventricle. 20, 20' restiform bodies or inferior peduncles. 21 calamus scriptorius or floor of fourth ventricle.
- 22 fasciculi graciles. 23 lateral columns. 24 origin of portio mollis nerve. 25 crura cerebelli or middle peduncles.

which project both downwards and outwards, the former composing the choroid plexuses of the lateral ventricles, the latter that of the 3rd ventricle. The velum is attached in front to the fornix. Below the 3rd ventricle, forming part of its floor, and in front of the pons, we see two flat bundles of fibres which ascend and diverge; these are the *crura cerebri*, or cerebral peduncles, the fibres of which are con-

tinuous with those of the medulla; anteriorly they are crossed superficially by two small converging cords, the *optic tracts*, which meet in front, thus with the crura enclosing a lozenge-shaped space, the *interpeduncular space*.

Fig. 286.



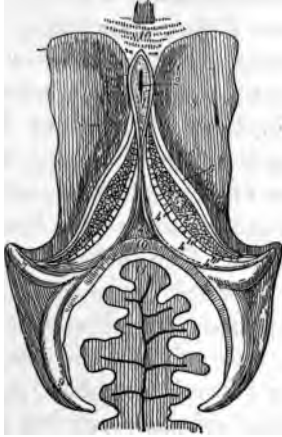
The brain from below.

- 1 frontal, 2 temporal, and 3 occipital lobes. 4, 5 great longitudinal, and 6 Sylvian fissures. 7 anterior perforated space. 8 infundibulum (pituitary body removed). 9 c. mammillaria. 10 posterior perforated space. 11 a crus cerebri. 12 pons Varolii. 13 cut end of medulla. 14 anterior pyramids. 15 cut roots of twelfth nerve. 16 lateral columns. 17, 17 lateral, and 18 'central' lobe of cerebellum. 19 olfactory sulcus. 20, 20 orbital convolutions. 21 optic tract. 22 olfactory stalk, at 22' cut away. 23 olfactory lobe. 24 chiasma. 25 third nerve-root, 26 fourth, 27 fifth, 28 sixth, 29 seventh, 30 eighth, 31 ninth, 32 tenth, 33 eleventh, 34 twelfth.

The tracts arise from the back part of the optic thalami, the nates, and corpora geniculata. At their union, termed the *optic commissure*, or *chiasma*, there is a partial *decussation* of the fibres, the *inner* fibres of the tracts crossing over; the cords then diverge again as the optic nerves. In the posterior perforated space—hind part of the interpeduncular space—are *two* small whitish rounded prominences placed side by side, the *corpora mammillaria* or *corpora albicantia*,

and in front of them is a slight elevation, the *tuber cinereum*, from which rises a conical process, the *infundibulum*, at the apex of which last is a small reddish body, the *pituitary*

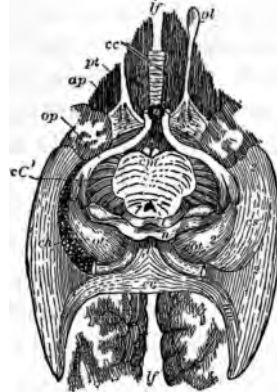
FIG. 287.



Horizontal section of central portion of brain.

- 1, 1 septum lucidum. 2 fifth ventricle. 3 corpus striatum. 4 fornix. 4' lateral parts. 4'' posterior pillar running into 4''' tænia hippocampi. 5 choroid plexus. 6 tænia semicircularis. 7 hippocampus major in middle cornu. 8 eminentia collateralis. 9 hippocampus minor in posterior cornu. 10, 10 corpus callosum. 11 grey cortical substance of cerebrum.

FIG. 288.



Part of the brain from below and behind. Partly dissected transversely just above the pons, showing the lateral ventricles, &c.

- lf, lf longitudinal fissure. ol olfactory lobe. cc corpus callosum. pt pituitary body. ap anterior perforated space. op optic tracts. cC crura cerebri. ch choroid plexus. ot optic thalamus. f fornix. l lyra. n nates. t testes. cm corpora mammillaria. hm hippocampus minor. 2, 2 lateral ventricle. cs corpus striatum.

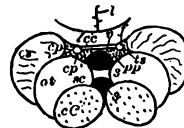
FIG. 289.



Transverse section of mesencephalon, middle part.

- 2, 2 lateral ventricles. 3 third ventricle. 5 fifth ventricle. f pillars of the fornix. f' their cut ends. cm corpora mammillaria. s septum lucidum. cc corpus callosum. l longitudinal fissure of cerebrum. cs corpus striatum. ot optic thalamus. cC crura cerebri.

FIG. 290.



Transverse section of mesencephalon, posterior part.

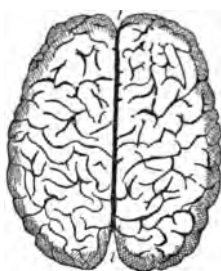
- Letters as before. sc soft commissure. pp pineal peduncle. ts tænia semicircularis. l lyra. v velum interpositum. cp choroid plexuses of lateral ventricles. cp' choroid plexuses of third ventricles.

body, which is received into the pituitary fossa (or sella turcica) of the sphenoid bone. On each side of the 3rd

ventricle is a rather large rounded body; these are the two *optic thalami*; developmentally they are thickenings of its walls, and correspond to the *hypoaria* of fishes. At the back of the optic thalami, and to the outside of the c. quad.^a. on either side are two small protuberances, the *corpora geniculata*, *internum* and *externum*. Before completing the description of the isthmus, other parts must be noticed.

144. The *cerebrum* is composed of two great lobular masses, the cerebral hemispheres, both attached to the isthmus, and indirectly as explained to the C^{llm}. cord, &c. The cerebrum in man (alone) is archencephalous—when viewed from above, it hides all the other parts of the brain. The grey matter of the C^m. is external. The surface of the C^m. is thrown into numerous folds called *convolutions*, or *gyri*, between which are fissures, or *sulci* of various depths. The convolutions may be divided into primary, secondary, and tertiary, the primary including several secondary, &c.; they are always arranged on the same general plan; but the details (especially the tertiary convolutions) differ very

FIG. 291.



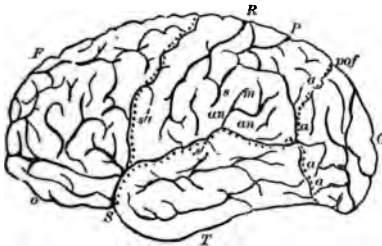
The cerebrum from above. *l, l* great longitudinal fissure.

slightly in different individuals, and in the two hemispheres of the same person, the sulci being very slightly more numerous, and a very little deeper (?) in clever men, according to some. The object of the convolutions is to furnish more of the grey matter with a liberal blood-supply, since the blood-vessels which enter the nerve-substance are very small, and for the most part do not penetrate far. In an average brain the free surface of each hemisphere is 110 sq. in., deep surface 220, total 330, total of both, 660 sq. in.

The hemispheres are partly separated (1) from each other by a deep longitudinal fissure into which dip the crista galli and falx cerebri, forming a septum, and (2) from the Cerebellum by the tentorium cerebelli; but the hemispheres are attached to each other by a transverse commissure of white fibres, the *corpus callosum*, seen below the fissure. Each hemisphere is divided into lobes, of which different authors count a different number; usually five are spoken of.

1, Frontal; 2, parietal; 3, temporal (or temporo-sphenoidal); 4, occipital; 5, central. A deep fissure—that of Sylvius—bifurcates and separates 1, 2, and 2, 3: a slight fissure, that of Rolando, passes partly down the centre of 2

FIG. 292.



The cerebrum, outer side, showing its division into lobes.

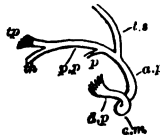
The dotted lines indicate the boundaries of the lobes.

F frontal. P parietal. O occipital. T temporal. pof peroccipital fissure. R fissure of Rolando. S Sylvian fissure. s' s' its longitudinal and perpendicular branches. o orbital convolutions. sm supra-marginal lobule. an angular convolutions. a, a annectant convolutions.

(some make this divide 1 and 2). 2, 3 and 4 are not very distinctly separated. The occipital, or posterior lobe (as such) is almost confined to man, being only found, as a small lobe, in the carnivora and higher quadrumana; the middle lobe is found in (all) mammals only. Into each fissure of Sylvius projects a group of convolutions, the *insula*, *island of Reil*, or central lobe: these are not externally visible.

145. In each cerebral hemisphere there is an irregular cavity; these two cavities are the *lateral*, or 1st and 2nd

FIG. 293.



The fornix.

p fibres going to pineal gland. d.p descending pillar. c.m corpus mammillare. a.p anterior pillar. t.s tania semicircularis. p.p posterior pillar. th tania hippocampi or corpus fimbriatum.

ventricles ; they are united to each other, and to the 3rd ventricle by a V-shaped canal, the *foramen of Monro*. Each lateral ventricle has three cornua, an anterior cornu passing into the frontal lobe, a posterior into the temporal, and a descending one into the occipital lobe. Two protuberances of no *particular* physiological importance are seen in the inner wall of each ventricle—the hippocampus major in floor of the descending cornu, and the hippocampus minor in the inner wall of the posterior cornu : they are simply due to some of the sulci being deeper than others.

146. On each outer wall between the anterior and descending cornua, and in front and rather to the outside of the optic thalami, are seen two rather large bodies, the *corpora striata*. The two islands of Reil correspond in situation to the corpora striata, which they cover.

147. Between the two lateral ventricles is a thin, double membrane, the septum lucidum, between the two layers of which is a small ventricle, the 5th. The septum lucidum is attached above to the corpus callosum, below to the fornix. The *fornix* consists of two cords or pillars : each pillar arises from the inner side of the optic thalamus, it then curves down and bends up again : the twist is seen externally as a c. mammillare ; the ascending portion is termed the anterior pillar ; at its upper end, where it touches its fellow, it sends off (1) a *tænia semicircularis*, which passes through the optic thalamus and joins it to the c. striatum, (2) a small branch to the pineal gland. The rest of the fibres then go back to form the posterior pillar : the two posterior pillars diverge behind, and adhere to the c. callosum, the interspace being filled by a delicate membrane, the *lyra*. Part of the fibres of each posterior pillar then spread out over the great hippocampus, and the rest run along its anterior margin in a small band, *tænia hippocampi*, also named from its appearance in section, corpus fimbriatum.

148. Across the interior of the 3rd ventricle pass three small cords of nerve-fibres, the anterior or hard commissure joining the c. striata, the middle or soft commissure, and the posterior commissure, both joining the optic thalami.

149. The optic commissure is united to the anterior end

of the c. callosum by a delicate layer, the lamina cinerea, or lamina terminalis, which forms the anterior wall of the 3rd ventricle.

150. Arising from the under surface of the anterior cerebral lobes are two bodies which project forwards, each consisting of a stalk and an ovoid bulbous head; these are *the olfactory lobes* (often called the olfactory nerves). Between their roots and the ophthalmic tracts is the anterior perforated space.

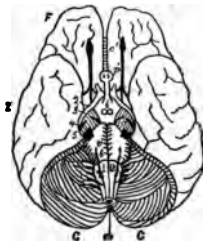
151. From the brain arise twelve pairs of cranial nerves.

(| motor, — sensory, + motor and sensory, * special sense.)

- 1 * Olfactory } are properly continuations of brain-substance, and not true nerves.
- 2 * Optic }
- 3 | Motor oculi, supplies all the muscles of eyeballs (except two) and the eyelid.
- 4 | Trochlear or patheticus, to trochlear muscle of eye and lachrymal gland.
- 5+* Trifacial, | to masticatory muscles, — to face and part of tongue, * for taste.
- 6 | Abducens or external rectus muscle of eye.
- 7 | Facial, muscles of expression.
- 8 * Auditory.
- 9+* Glosso-pharyngeal, + to tongue and pharynx, * subserves taste.
- 10+ Pneumogastric or vagus, supplies pharynx, larynx, lungs, and heart, and is intimately connected with the sympathetic system.
- 11 | Spinal accessory, part of it joins the pneumogastric.
- 12 | Hypoglossal or lingual, to muscles of tongue.

Sometimes 7 and 8 are respectively called the portio dura and

FIG. 204.



Brain from beneath, showing origin of nerves, &c.

- f frontal, and t temporal lobes.
- c cerebellum.
- c' corpus callosum.
- p pituitary body.
- i infundibulum and corpora mammillaria.
- e a crus cerebri.
- v pons Varolii.
- m medulla oblongata.
- 1 olfactory lobe and stalk.
- 2 optic tracts and commissure.
- 3—12 roots of the other cranial nerves.

portio mollis of the 7th pair; 9, 10 and 11 being spoken of as constituting the 8th pair, and 12 the 9th pair.

FIG. 295.



Diagram of the origin of the cranial nerves.
 1-12 the twelve nerves. *ot* optic thalamus. *tq* tubercula quadrigemina.
pV pons Varolii.

FIG. 296.

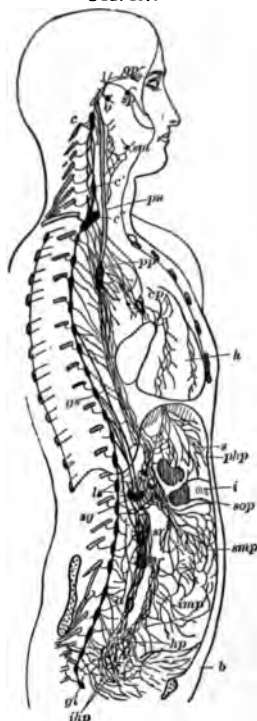


Isthmus, side view.

ot optic thalamus. *cg*, *cg'* corpus geniculatum, internum and externum.
p pineal gland. *n* nates. *t* testes.
cO crura Cerebri. *pV* pons Varolii.
a, *c*, *c'* superior, middle, and inferior cerebellar peduncles (cut through).
o olivary body. *r* restiform body.
ap, *pp* anterior and posterior pyramids. 2, 3, 4, 5, 6, 7, 8 roots of the corresponding cranial nerves.

152. The sympathetic system consists of the prevertebral

FIG. 297.



The sympathetic system.

op ophthalmic ganglion.
sp spheno-palatine or Meckel's ganglion.
o otic or Arnold's ganglion.
sm sub-maxillary ganglion.
c, *c'*, *c''* superior, middle, and inferior cervical ganglia.
 Between *d'*—*gi* the dorsal, lumbar, sacral, and coccygeal ganglia.
pn pneumo-gastric nerve.
cp cardiac plexus.
pp pulmonary plexuses.
h heart.
s stomach.
php phrenic plexus.
i intestines.
sop solar plexus.
emp, *imp* superior and inferior mesenteric plexuses.
hsp hypogastric plexus.
ilp inferior hypogastric plexuses.
b bladder.
gi ganglion impar.
gs great splanchnic nerve.
ls lesser splanchnic nerves.
sg solar ganglion.
sr supra-renal plexus.
r renal plexus.
a aortic plexus.

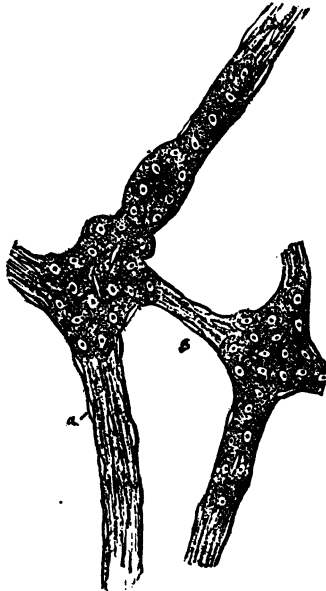
chain, the ganglia of the posterior roots of the spinal cord, and numerous scattered isolated ganglia, connected with each other, and with the cerebro-spinal system by fibres.

(1) The prevertebral chain, or the 'great sympathetic,' consists of about twenty-nine or thirty pairs of ganglia (cranial 4, C 3, D 12, L 4 (or 5), S 5, C 1), each connected with its fellow and neighbours, and with the irregular ganglia,—there being usually one to each rachidian, or spinal nerve; they are connected with all the cerebro-spinal nerves (except the olfactory and optic nerves). The chain unites above in the palate, behind the upper incisors, below in front of the coccyx, in the ganglion impar, from which fibres run downwards to terminate ultimately, perhaps, in the coccygean gland.

(2) The posterior-root ganglia appear as enlargements, one upon the posterior root of each spinal nerve.

(3) The irregular ganglia are mostly abdominal in situation, and are for the most part gathered into three large

FIG. 236.



Part of a Meissner's plexus. (After Quain.)

Two ganglia are represented. *a*, a nuclei of connective-tissue corpuscles.

plexuses, connected together, and supplying other smaller secondary plexuses. (A) The cardiac supplying the heart,

&c.; (B) the solar, consisting chiefly of two 'semi-lunar' ganglia, and supplying the majority of the viscera, (C) the hypogastric supplying the pelvic viscera. In the walls of the intestines are two minute ganglionic networks derived from the sympathetic. (1) Auerbach's, found in the small intestine between the circular and longitudinal muscular layers, but in the large intestine outside the longitudinal layer. (2) Meissner's, found in the sub-mucous tissue of some parts of the intestines. Sympathetic nerve-fibres frequently have minute ganglions upon them near their peripheral terminations. There are minute ganglia in the walls of the heart and elsewhere.

153. The histology of the nervous system is extremely complicate. The nerves consist of both sensory and motor fibres: the *posterior* roots are *sensory* only, the *anterior* motor only. The fibres of the posterior root go into the postero-lateral fissure and posterior columns, then run in all directions up and down, some passing around the grey posterior cornu, others into it; all the fibres probably passing into it sooner or later. The prolongations of the posterior cells (cells of the posterior cornu) form an anastomosing network, connecting neighbouring cells, and into this network run the posterior fibres; the prolongations of the anterior cells also form a network which unite its cells together; these networks unite into one group the cells of the two cornua which pass insensibly into each other: the whole grey matter of the cord is also thereby united into a great plexus. The axis-cylinders of the anterior nerve-roots pass directly into the anterior cells. Small fibres pass up from both sets of cells to the brain; but whether any fibres, either motor or sensory, pass directly from the nerve-roots to the brain, without being first connected with the cells of the cord, is not known—probably not any (or but a very few). The white matter of the cord is mostly composed of these longitudinal fibres, passing upwards and downwards; but the grey matter also contains some of these longitudinal fibres,—there smaller. There is most grey matter at the enlargements; the grey matter increases downwards *relatively* to the white,—the lateral white columns

especially diminishing downwards. In the medulla oblongata the grey and white matter is intermixed, as also in the optic thalami, and c. striata,—that of each c. striatum being mostly gathered into three nuclei. In the cerebrum and cerebellum the grey matter is external, the white internal. The grey matter as usual consists of cells and minute fibres, but here also contains much free granular matter and free nuclei. Connective-tissue is found in both the white and grey matter, partly as a delicate gelatinous matrix containing minute nuclei,—the neuroglia,—in which are embedded the nerve fibres and cells,—partly as firmer fibrous septa and trabeculæ, which ramify in the white substance: it also surrounds the cord with a sheath, the inner part of which is

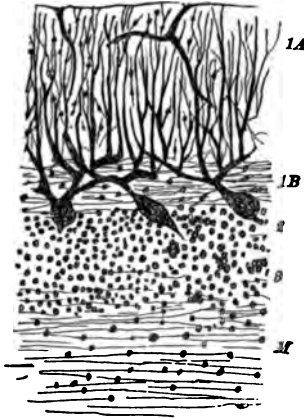
FIG. 299.

*Neuroglia from spinal cord. (Kölliker.)*

gelatinous and sends down prolongations which ramify and ultimately become continuous with the neuroglia.

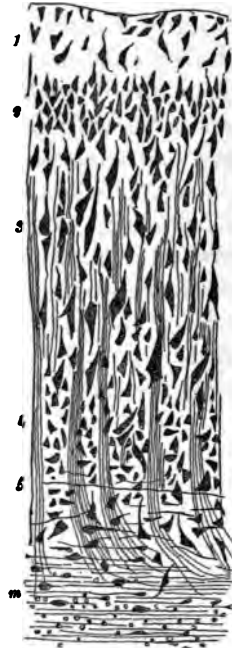
The grey matter or cortex of the Cerebellum consists of three layers; (1) an external one, consisting of a connective-tissue matrix, and nerve fibres with a few small granular cells, apparently nucleolated nuclei occasionally, having around them some protoplasm which may be branched; (2) a layer of very large granular cells, those of Purkinje, each having a nucleolated nucleus, and sending a short process downwards, and one (or more) branched one upwards: the branches run throughout the whole of the external layer, and are sometimes connected with the small cells there; (3) an inner layer of granular cells, or nucleolated nuclei, lying in a gelatinous matrix, which also contains fine nerve-fibres; occasionally these cells have protoplasmic branched envelopes, like those in the outer layer: this layer gradually passes into the white medulla.

FIG. 300.

*Section of cortex of cerebellum.*

1A external, 1B internal portions of grey layer. 2 layer of Purkinje's cells. 3 granular layer. M medullary centre.

FIG. 301.

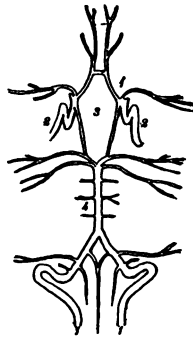
*Section of cortex of cerebrum. (After Meynert.)*

1 superficial layer of scattered corpuscles. 2 layer of close-set angular corpuscles. 3 layer of large pyramidal corpuscles. 4 layer of close-set irregular corpuscles. 5 layer of fusiform corpuscles. m medullary centre.

The grey matter, or cortex, of the Cerebrum is about $\frac{1}{8}$ in. in thickness, and surrounds both the free and deep surfaces. It is most abundant, and better defined in the postero-lateral portions. The cells seem mostly to be pyriform, the apex of each sending a prolongation outwards, the base several inwards. It is divided into seven layers: two outer pale layers, with few cells; one greyish middle layer, with very numerous cells; four reddish-yellow inner layers. The seven layers are well defined in the posterior lobes, but are reduced to about four layers in the anterior lobes, the seventh, or inner layer, being represented by only a few cells scattered among the white fibres of the medulla. The cells of the external layers are small, and have plexiform posterior

cornua resembling sensory cells,—those of the deep layers many of them being large and pyriform, like motor cells. The fibres in the various layers are *in all probability* in connexion with the protoplasmic prolongations of the cells, and connect together most intimately all the layers, and parts of the same layer. Upon the inside of the cortex is a thick layer of fibres of three classes; (A) associating fibres, which join neighbouring parts of the grey substance; (B) commissural fibres, joining the two hemispheres (c. call^m, &c.); (C) radiating or converging fibres, which run (1)

FIG. 302.

*Blood-supply of brain.*

1 intervertebral arteries. 2 internal carotids. 3 circle of Willis. 4 basilar artery.

from anterior lobe to c. striatum; (2) from the other lobes to the optic thalamus: some of the fibres stop in these ganglia, others pass on to the medulla-oblongata, with fibres derived from the cells of these ganglia. Since the blood-supply of the brain is liable to great variation, there is a supply of large lymphatics, which furnish the blood-vessels with an extra coat, forming a lymph sinus around them, the diameter of the canal being about two or three times as great as that of the vessel in its centre. Besides this, the cephalo-rachidian fluid is capable of great variation in quantity, and is in inverse ratio to the blood-supply. The fluid in the arachnoid sac and the root-pouches may also aid.

The cells in the posterior cornua, and in the posterior parts of the brain, are smaller than those in the anterior,—the larger cells being intermingled with the others: the

large pyriform cells are found in the 5th and 6th (inner) layers of the C^m.

In intercommunication of the cerebro-spinal and sympathetic systems there is a mutual interchange of fibres, about two-thirds being derived from the C-S; but the sympathetic has also its own proper fibres. The fibres from the C-S (cerebro-spinal), many (—perhaps, but *very improbably*, all) of them pass through the ganglia without being connected with their cells. The C-S system sends both motor and sensory fibres to the sympathetic.

154. *Sensory* nervous impressions, if entering the cord at the posterior roots of the *right* side, pass into the plexus of the right posterior cornu, from which fibres run upwards, going over immediately to the left side, and running up the grey matter of the left posterior cornu, and possibly a few fibres surrounding it: thus, decussations of sensory nerves occur the whole way up the cord; finally, the impressions go to the left optic thalamus, and *left* cerebral hemisphere.

FIG. 303.

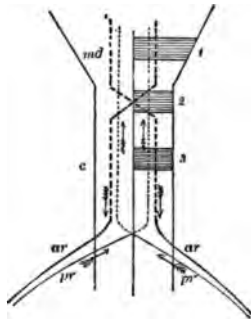


Diagram showing the course of the motor and sensory fibres of the cord and medulla.
 mo medulla oblongata. c spinal cord. a, p anterior and posterior nerve-roots. The arrows indicate the direction of the nerve-currents. The section at 1 would destroy (voluntary) motor power and sensation on the opposite side; at 2 diminishes motor power on both, destroys sensation on opposite side; at 3 destroys motor power on the same, sensation on the opposite side.

Voluntary *motor* impressions, if from the *right* side of the brain, pass down the right anterior pyramid, decussating in its lower part pass over to the left lateral spinal column, down this a little way, then down the left anterior column chiefly, but also down the left lateral and left grey cornu, finally passing out by the left anterior roots. Almost (but

not quite) all the motor nerves decussate in the medulla, but a few also decussate in the cord; these last are very possibly those which do not decussate in the medulla.

155. Of the exact physiology of the nervous system, there is, perhaps, less definite knowledge than of its histology. The cells receive impressions and discharge nerve-force: the fibres simply conduct these currents. The motor cells are usually much larger than the sensory ones. If a fibre possess a cell on its course, it should be considered functionally as two fibres. Nerve-force somewhat resembles electricity, and a current of it in man travels at the rate of 111·22 ft. per sec., or more probably about 200 (88—308). A nervous current produces in the nerve-fibre along which it travels a wave of negative variation, which (if the fibre end in a muscle) produces a somewhat similar but slower wave of negative variation in the muscle-fibre, flowing both ways from end-plate (and spreading to neighbouring fibres). This muscle-wave, which travels 9 ft. (13 ?) per sec., is immediately followed by a wave of contraction, lasting $\frac{1}{20}$ sec., during which the muscle shortens, and becomes more extensible; an increased amount of oxygen is absorbed, whilst much more carbonic acid, and some sarcolactic acid are given off. It takes about $\frac{1}{8}$ sec. to receive a sensation, register it in the brain, and signify it by a muscular movement, including conduction, and muscular contraction (the reflex action itself occupying $\frac{1}{10}$ — $\frac{1}{30}$ of a sec.): if it is required to notify also on which side of the body, ·067" must be added in case of touch, ·077" sight, ·149" hearing: to distinguish between colours or letters about $\frac{1}{8}$ ", sounds $\frac{1}{3}$ — $\frac{1}{20}$ ", touch (between two impressions) $\frac{1}{12}$ " : this process is rather longer in the case of *unexpected* sensations.

156. The nervous system connects into a co-ordinated organism every part of the body. It is always active, receiving chemical and physical stimuli from, and acting upon, the different parts,—usually unconsciously. Each organ has practically its own proper stimulus, e. g. irritation of the conjunctiva and the secretion of tears, blood deficient in oxygen upon the vagi causing the respiratory movements, the blood upon the heart causing its beating. The organic

functions are not normally perceived as such (by the brain), those of the animal system are.

157. Motion is of three kinds. (1) Purely involuntary and often continual, as the action of the heart, &c., and of non-striated fibre. (2) Reflex voluntary (generally included amongst the involuntary) produced by some irritation, but without the co-operation of the will, e.g. sneezing, coughing, contraction of legs when soles of feet are tickled. (3) Purely voluntary, produced by direct operation of the will. Reflex movements are, to a certain degree, under the control of the voluntary (e.g. winking); but, if opposed, the reflex finally overcome.

158. The principle of operation of the nervous system is as follows: a ganglion consists essentially of a body of nerve-corpuscles, with which are connected nerve-fibres, afferent and efferent: (grey matter is always ganglionic): an afferent fibre receives and conveys an impression of some kind in a centripetal direction up to its ganglion,—the disturbance here produced gives rise to a motor impulse, which runs in a centrifugal direction down an efferent fibre (causing a muscular contraction of the part supplied by it, if the fibrils are peripherally distributed to muscle). A movement seems to be considered more voluntary according to the ganglion called into operation in producing it,—the nearer to the cerebrum the more it partakes of a voluntary nature. The more voluntary actions are, the more intermittent; thus, there are no purely voluntary ones produced by the cerebrum during sleep.

159. In speaking of the sympathetic as the system of organic life, and the cerebro-spinal of animal life, only popular terms are used, for their exact functions and amount of dependency or inter-dependency are not precisely known. The sympathetic system appears to have control over the organic functions only, supplying *non-striated* fibre, secretive and absorptive systems, &c.; but as it receives numerous fibres from the C-S system, it is possible that one great function is to modify the impressions so received, thus being so many centres of distribution. That the C-S system affects the Symp. we know for certain. The conduction or action of the Symp.

as compared with that of the C-S is slower, *more* diffusive, regular, rhythmical, and involuntary. The Symp. ganglions are probably all of them independent centres, mutually influencing each other, and being influenced by the C-S system: also (especially in cases of disease) influencing the latter: some have considered them to be the inductors of nerve-force. The C-S system, though the centre of animal life, also controls the organic system, and the Sympathetic. Both systems mutually affect each other: notice the effect of love and of fright upon the heart,—of shame and fear upon the hypogastric region,—weeping,—sea-sickness,—the smell of oranges upon the secretion of saliva,—imaginary hydrophobia; and, on the other hand, of biliousness, and of illness generally in depressing the mind.

160. An impression, having been received by the sensory posterior nerve-root upon entering the cord, produces a disturbance in the cells, &c., of the posterior cornu; this produces two effects: the impression is transmitted (1) forwards to the cells of the anterior cornu, and these being called into action, give off a motor impulse, which passes out by the anterior motor root, and produces muscular contraction of the parts supplied by the nerve; this constitutes a purely *reflex* action: (2) upwards to the brain, where (if that organ be awake) it is perceived as a sensation, and this may, if strong enough, give rise more or less directly to an action of the will, which would send an impulse down to the anterior cornu and anterior nerve-root, thus producing a muscular contraction of the voluntary type.

161. All apparently-voluntary actions are not always so; thus there are (1) instinctive, or sensori-motor actions, e.g. sucking, balancing the body; (2) emotional and ideo-motor actions (both allied), e.g. of the former, the expressions of emotions, as smiling, &c.; of the latter, yawning upon seeing another person do so. (3) Acquired reflex, or secondary automatic actions, acquired by habit and training; they are practically sensori-motor, since instinct is due to organization, e.g. a soldier upon march, halting upon the word of command being given, whilst thinking of something

alien ; playing a well-known tune upon the piano whilst talking, and many mechanical movements. The effect of habit is at first to make the performance of actions easier, then mechanical and reflex, e.g. playing a difficult tune, performing juggling feats : the difficulty of drawing a circle will show to what extent we are indebted to habit in our movements. The contraction of the necessary muscles when standing is partly due to reflex stimulus of resistance, caused by the exercise of antagonistic muscles.

162. The rapidity and accuracy with which muscular movements (to which we are accustomed) can be made, is almost incredible : 1500 letters may be said during a minute, each contraction thus occupying only $\frac{1}{35}$ sec. (contraction being followed by a nearly equal period of relaxation does not in this case apply) : again, the vocal cords in singing can be changed by a good singer about as little as $\frac{1}{1200}$ in. ($\frac{1}{17000}$ in one person [?] !) : the feats of jugglers are equally wonderful, as also is the delicacy of manipulation of diamond polishers.

163. The laws of reflex action are (1) that of unilateral reflection,—the movement produced affects the same (if only one) side, (2) of symmetry,—if the two sides, the corresponding muscles of the opposite side, (3) of intensity,—the movements of the opposite side are never stronger (usually weaker) than those of the irritated side ; (4) reflex irradiation, the motor nerve excited is always on the same plane as the sensory nerve : if the sensation be very powerful, it may affect nerves above but not below that plane.

164. The functions of the spinal cord are, by its fibres to connect the brain and spinal nerves, and by its ganglionic matter to give rise to reflex actions. Theoretically, the medulla oblongata is functionally but little more than a part of the cord. In it is the centre of the pneumo-gastric nerve, and so the chief centre of respiration ; and, as this is one of the most important functions, death generally ensues almost immediately upon severing the medulla horizontally between the points of origin of the glosso-pharyngeal and pneumo-gastric nerves : this was called the 'vital point;' death does not, however, invariably ensue immediately. The medulla

also contains the centres of the vaso-motor system, of cardio-inhibition (?), of deglutition, vomiting, the stomach, &c., secretion of digestive juices, &c. The corpora quadrigemina are intermediate centres of sight. The functions of the pineal and pituitary glands are quite unknown, and apparently unimportant; but these organs are present in all vertebrates. The optic thalami are generally looked upon as intermediate *sensory* centres, the sensory fibres of the cord which go to the brain mostly passing through them, and some of the fibres being connected with its cells on the way. The corpora striata are generally considered to be similar intermediate *motor* centres, but by a few are thought to be part and parcel of the cerebral hemispheres; the fibres of each, in passing to the isthmus are partly surrounded by the optic thalamus of its side.

165. The functions of the cerebellum has been a subject of great controversy. (1) The old opinion was that it was the chief centre of the sexual functions; this now seems to be confined to and around the central lobe, *if* in the C^{lm} at all. (2) The *co-ordination of muscular movements* (in space, not time); but this is carried on to a certain extent by the cord itself, the nerve-plexuses of which combine together groups of cells, and the consequent action depending upon the extent of the stimulus spreading (according to the laws of reflex irritation) to neighbouring groups, thus accounting for the inter-dependency of certain muscles, and of the parts of the same muscle. (3) Perhaps the chief centre of the muscular sense; thus the muscular sense nerve-fibres would be the sensory fibres of the C^{lm} , and the co-ordinator fibres its motor fibres. The C^{lm} may regulate the bodily equilibrium, and control the strength of muscular movements; and this latter function may take place by means of the motor fibres returning (after forming a loop) to the C^{lm} as muscular sense fibres,—*recurrent* fibres among muscles having been described. It has been suggested that the median lobe is the centre of muscular, the lateral lobes of cutaneous sensibility.

166. The functions of the cerebrum seem to be all the higher operations of intelligence depending upon conscious-

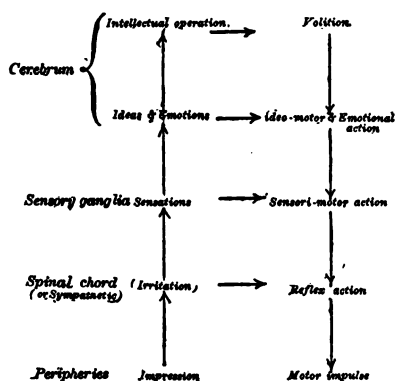
ness, termed the mental faculties, which may be divided into three groups:—A. Feeling (Sensations, Emotions); B. Thought or Intellect (Discrimination, Agreement, and Memory, involving Association, Reasoning, Classification, &c.); C. Will or Volition.

Into any explanation of brain physiology I shall abstain from entering, as being unnecessary, and without the scope of the present work. It will suffice to notice (1) The Law of Conservation: whatsoever tends to increase the vitality of a part or the whole is (usually) pleasant,—to diminish it, painful. (2) Action, within due limits (of whole and parts), is healthy, and more or less pleasurable according to force stored up in that centre: a miserly saving of foot-pounds does not increase vitality—life-store, for action is necessary to life. (3) Note also the capacity for improvement and development generally, and especially in any particular direction (though slightly at expense of the rest usually—one part being able to draw upon the rest).

Whether the various functions of the brain are localized in any particular parts is uncertain, but highly probable: their supposed localization constitutes the science of Phrenology, invented by Gall, whose system has been received and developed by his followers (Spurzheim, Redfield, Harrembert, Wells, &c.) with wonderful unanimity, and usually allied with Physiognomy. The data of his system are false, and at best are only founded on external appearances to which there is no apparent internal correspondence whatever. That there is a localization is, I think, *certain*, though probably a very complicate one, and one which very possibly divides the cortex into layers as well as pieces cut vertically, as now considered.

167. An impression received peripherally passes up to the spinal cord, there exciting reflex action, and passing farther up excites sensori-motor actions, farther on ideas, emotions, and ideo-motor and emotional actions, and still farther reflection: reflection gives rise to conception of result with desire to accomplish it; and this to actuation, the desire assuming a definite form; finally arises volition, which produces a voluntary action.

FIG. 304.



168. During sleep the brain (excepting the medulla oblongata) is inactive. The cause of sleep is by some thought to be (1) exhaustion of the brain, like that of an electric battery; but it probably has a more immediate cause — (2) insufficiency of oxygenation of the blood, more oxygen comparatively being absorbed during the night than the day, surplus producing waking; (3) some have conjectured that during wakefulness there is (local) hyperæmia, during sleep venous congestion; the former seems to be true, but the latter not so; (4) *want of blood-supply* to the brain: it has been actually observed that the blood-vessels of the brain (C^m , C^{lm} , and ganglia at the base) diminish very much during sleep, not so those of the medulla and cord; hence reflex actions may take place during sleep, but voluntary ones do not. True sleep is devoid of dreams, which are due to the C^m being partly active; the main feature of dreams is the absence of reasoning power, especially in not noticing incongruities, the imagination being rather abnormally active. Dreams seem to be sometimes confined to the early stages of waking, but generally are not so; N.B., a dog 'hunting in its dreams,' and nightmare. Somnambulism is of various kinds and degrees, and is a peculiar and abnormal form of dreaming: it seems allied to the state of a person under the influence of animal magnetism. The vast majority of spectral illusions resemble

dreams, and are due to cerebral disturbance,—undue activity of some part connected with vision.

169. The nervous system receives impressions of various kinds, and it is thought by some that the different impressions are conveyed by different fibres, and that some of these collect into groups in the spinal cord. The quality of the impression usually depends upon the *peripheral termination* of the fibre (very probably upon the central termination also), and not upon any quality of the fibre itself; but whether touch- and pain-impressions for instance are conveyed by the same or different fibres is unknown. It has been proved that the same fibre *can* convey motor and sensory impressions. The following thirteen kinds of fibres are noticed by Brown-Séquard and others. A. *Sensory*, 1 touch, 2 temperature, 3 pain, 4 tickling, 5 sexual feeling, 6 muscular sense, 7 pressor, 8 incito-motor, 9 incito-secretory: B. *Motor*, 10 voluntary, 11 involuntary, 12 vaso-motor, 13 nutritive and secretory. The last two are rather antagonistic and require notice. The vaso-motor nerves are distributed to the coats of the smaller arteries, and by their action diminish (and so regulate) the blood-supply to a part. They are derived immediately from the Symp. system, but most of them at any rate come originally from the C-S system; the medulla seems to be the great centre of them. There seems also to be an antagonism between the vaso-motor system and other nerves generally: thus, if a great demand be made upon the nerve force by violent muscular exertion, the vaso-motor nerves become temporarily somewhat paralyzed by the exhaustion of their nerve-force, and perspiration ensues—the more readily in weak persons. The emotions also affect this system in both ways, e. g. blushing (paralyzed action), paling with terror (stimulated action), &c. The vaso-motor nerves perhaps possess a set of sensory nerves proper to them—these are the pressor nerves. The nutritive and secretory nerves act upon tissues (chiefly on cells, e. g. in glands) by increasing chemical interchange, and so also inciting more blood to the part, and causing capillary expansion: they do not always seem to exist, and at least in muscular fibres are not recognizable

as distinct fibres. Touch and temperature seem to be conveyed by separate fibres, but the existence of special fibres of tickling I very much doubt; see § 178.

170. The following experiments and deductions are to be noticed. If a nerve be severed, it becomes useless for the transmission of impressions. If a sensory nerve-root be cut, and the central end irritated, the pain is referred by the brain to the parts formerly supplied by the nerve; this is the result of habit. If the nerve-centres be irritated, the ensuing sensation is termed subjective, the proper sensation being termed objective; the images presented to us in our dreams are examples of subjective sensations. Sensory impressions are usually judged by *pain*, and if this is conducted by proper fibres, many of the experiments must be limited in value. Some believe that the motor fibres run in the anterior and lateral spinal columns: those of tactile and of muscular sense (neither decussating) in the posterior column, those of pain in the grey matter, the pressor fibres (some decussating) in the lateral. The anterior nerve-roots convey motor impressions only,—posterior, sensory only; the sensory impressions travel up the grey matter only of the cord,—the motor down grey only (?) or nearly so,—very probably down the anterior columns and anterior two thirds of the lateral columns, and passing into the grey matter below. The white matter of the cord is quite insensitive, except on the surface and around the posterior cornua and posterior nerve-roots, so that it would seem that the sensory fibres of the cord itself, which run up from the posterior plexuses, are insensitive. The anterior columns are very excitable (i. e. produce muscular contractions upon irritation) in their lower part, *vice versâ* in the upper parts; the lateral columns are similar in this respect, but not so noticeably. What may be the functions of the fibres found in the posterior columns, and those at the top of the anterior columns, which are both insensitive, is uncertain—very probably the posterior ones are connected with the muscular sense and the co-ordination of movements; the others, perhaps, with muscular tonicity and organic functions. The lesion of the posterior columns in locomotor

ataxy seems to involve (only) the fibres conveying impressions of muscular sense and co-ordination. If the whole cord be severed, the parts supplied by the portion below the point of section become paralyzed, and incapable of transmitting sensory impressions to the brain: and so we lose feeling in the parts and also lose muscular control over them, but *reflex* actions still continue to be performed. If the cord be partly severed, the functions of the part below are weakened. If one half of the cord be severed, all sensation from the opposite side of the body (that is, of course, only the parts supplied by the severed portion) is destroyed, but the motor power of the same side is lost; but if one half of the upper part of the medulla be severed, sensation on the same side, and motion on the opposite, are lost. A longitudinal antero-posterior section of the cord destroys sensation of the parts immediately below for a limited distance only down the cord, but leaves the motor power uninjured. A section of the grey matter destroys sensation, and also voluntary motor power, but destruction of the anterior columns also destroys, and of the lateral columns slightly weakens the motor power, at least temporarily.

If the tubercula quadrigemina are destroyed, blindness ensues. If the optic thalami are cut away, nearly total loss of sensation is the result, and motion is slightly injured: if the corpora striata are ablated, motion is nearly destroyed. If the cerebellum be cut away, the animal cannot stand, or perform any complex movements, though some think that this is simply due to vertigo, or giddiness. If the cerebrum be taken away, the animal becomes stupid and almost inert; though it moves, can preserve its equilibrium, and can see; will follow the movement of a candle with its head, but has no sense to avoid any object seen; will start at a sudden sound, occasionally open its eyes with an absent stare, smooth its feathers (if a pigeon), and then relapse into a state of lethargy,—or, if thrown into the air it will fly; if pinched, an animal will cry, but probably does not feel any pain; or, if the pain be felt, it is not remembered, since it has no memory to register it, the cry being very probably of reflex origin, e. g. in epilepsy, a local medullary

origin: thus it seems to perform all reflex movements, and many sensori-motor ones (e. g. swallow food, &c.), but no purely intellectual ones; so the consciousness which the medulla and subordinate parts of the brain seem to possess is of comparatively small importance in man, and the higher vertebrates. *Possibly* the optic thalami are the seat of perception, and the corpora striata of motor intuition. If part of the C^m be ablated, or destroyed by abscess, no noticeable effect usually takes place. If one hemisphere be ablated, the other will gradually assume its functions (all?), both halves being naturally associated by the corpus callosum, absence of which has been observed (in one or two instances) to accompany want of forethought. The whole C^m and the isthmus may be extracted, without immediately destroying life, the main centres of which seem to be in the medulla oblongata and tuber annulare. The C^m and C^{llm} are possibly trophic (nutritive) nerve-centres also.

171. Many subordinate parts of the encephalon give rise, when irritated, to convulsive movements of certain muscles, producing rotatory movements of the body. The animal (1) may run round in a ring; (2) may turn upon its hind legs as the axis; (3) with its injured side as the axis; or (4) may roll—revolve upon its own axis (i. e. of its body). The movements may be to the right, or to the left side, according to the part irritated.

172. The cerebrum and cerebellum are usually insensitive, and inexcitable, but by electricity various centres of muscular movements have been discovered by Fritsch and Hitzig, and by Ferrier: the former authors, however, deeming them to be connected with muscular sense rather than with voluntary motion. Goltz denies the localization, and finds that the effect is proportionate to the lesion, and is similar whatever part of the hemisphere be ablated: if a whole hemisphere, the functions are weakened, some, perhaps, lost; thus a dog taught to present either paw would, after the lesion, invariably give but the one.

Anterior frontal regions, unpossessed of motor influences, a chief seat of intelligence, especially of observation.

Convolution dividing the fissure of Rolando, voluntary motion of opposite side of the body.

Destruction of the angular gyrus causes temporary loss of sight in opposite eye ; if both are destroyed, permanent blindness.

Superior temporo-sphenoidal convⁿ, hearing.

Hippocampus major and its convⁿ, touch on opposite side.

Gubernaculum cornu Ammonis, or tip of uncinat convⁿ, smell on same side.

Lower part of temporo-sphenoidal lobe, taste on opposite side.

Occipital lobes perhaps connected with systemic sensation (not sexual appetite), their destruction causing depression, and a rejection of food.

The centres for the hind-limbs are nearest the longitudinal fissure, then come those of the fore-limbs, and outside these the centres of the ocular and facial muscles.

Muscles of the neck, middle pre-frontal and angular conv^{na}.

Extensor and abductor muscles of the fore-leg, end of post-frontal convⁿ next to the frontal fissure.

Flexor and rotator muscles of fore-leg, at the back of this, and nearer the coronal fissure.

Centres of the hind-leg, post-frontal and ascending parietal conv^{na} also, but nearer its middle and back parts.

Back, tail, and abdomen, last named centres, but not accurately determined.

Portio dura, middle super-Sylvian convⁿ

Muscles (and faculty) of speech, last tier of third frontal convⁿ

The voluntary motor power thus seems to be chiefly confined to the anterior lobe, anterior part of the parietal, and upper part of the temporal lobes ; hence it has been inferred that the rest of the brain—the posterior part—presides over sensations : emotions *possibly* belong to the posterior part, reasoning and arrangement of thought more to the fore-part. It has been suggested that the pre-frontal region presides over attention and controlling functions, the occipital lobe over cœnæsthesis.

Irritation of the corpora striata produces rigid pleurosthotonos, the flexors predominating over the extensors. Irritation of the C^a quad^{na} produces movements of the iris (testes contract, and nates dilate pupil), and contraction of the extensor muscles of the body. The C^{lim} appears to be the co-ordinator of the muscles of the eyeball, and upper limbs ; but the whole C-S system seems to be engaged in muscular co-ordination. Many of the movements produced by irritating subordinate parts are probably due to *reflected irritation*, and thus unfortunately the experiments upon the brain are of but *dubious value*. We should also note vicarious functions : if a gland or a nervous centre be extirpated, its allies take its functions, as far as possible, upon them-

selves; most organs have others slightly allied to them,—one advantage of a not too complete organic differentiation.

178. Two peculiarities of nervous function must be noticed. I. *Inhibitory action*, by many supposed to be produced by inhibitory fibres. The heart is supplied with nerves by the ganglia in its substance, by sympathetic, and by pneumogastric fibres. The action of the heart is due to the ganglia, for it will contract after separation from the body. Stimulation of the sympathetic causes increased rapidity of action, whilst stimulation of the pneumogastric diminishes the frequency, and, if sufficiently strong, arrests it: and as this inhibitory action is neither due to spasm nor exhaustion, it must be due to the peculiar restraining influence of some, at least, of the pneumogastric fibres. The heart seems to possess besides its central active ganglion, two other intermediate ones, (1) an inhibitory one, connected with the pneumo-gastric, and (2) an accelerating one, connected with those fibres of the pneumogastric which usually run through the sympathetic. The heart's action (frequency, &c.) usually varies inversely as the peripheral resistance: its chief regulative centres being in the medulla. There are other instances of inhibitory action, besides that of the heart. Inhibition takes place through the medium of the nervous system, which contains regulative centres, inhibitory and stimulative, usually in antagonistic interdependence,—the one, if stimulated, drawing upon the other. Otherwise it would be difficult to understand how muscle (striated or non-striated) could be affected in two opposite ways, unless we supposed that there was an interference of nerve-currents in some way. In the glands the action may be explained by the antagonism of the vaso-motor and the secretory nerves. II. *Transferred sensations*: e.g. obstructions in the bronchial tubes produce irritation of the larynx; thus, a person with a cough complains of laryngeal irritation, and usually of that only: possibly it is that the ganglionic centres of both parts are very close together in the medulla, and thus both are affected; but the more irritable centre the more so, as is often the case in disease: the sensory-circle theory (see § 180) is insufficient to explain the phenomenon.

CHAPTER VII.

THE SENSES.

174. THE body possesses the capability of common sensation, which comprises feeling and touch with their various modifications. Feeling may be regarded as internal or organic,—touch as external or animal. These sensations are conveyed to the brain by the sensory nerves, but whether by the same, or different fibres, or if by different ones, whether these are similar or slightly different, is unknown.

175. *Feelings* are of various kinds: we become acquainted with them by what has been termed *cœnæsthesia*, a compound sense, including various sensations, which may be grouped (rather indefinitely) according to their chief seat of origin. (A) *General*: 'Bien-être,' Malaise; (B) *Special*: Fatigue, Repose; Languor and Listlessness; Thirst, Inanition, Impeded circulation, Faintness; Shortness of breath, Suffocation, Closeness, Exhilaration upon going into fresh air; Relish, Repletion, Nausea, ('Heart-burn'); (internal) Heat and Cold, &c. Electrical conditions of the atmosphere are also felt,—negative electricity (as before a thunderstorm) depressing; positive tides, when high (twice daily, about 9 a.m. and 6 p.m.) elevating. The influences of atmosphere (climate, &c.) are chiefly due to (1) humidity, (2) density, (3) temperature, (4) electricity, and (5) quality (ozone, miasma, &c.). Note (1) the effects upon feelings of foods, stimulants, medicine, and of diseases; (2) the various kinds of pain.

176. The various appetites (sensori-motor desires) dependent upon these feelings, are: restlessness, desire of exercise, lassitude, &c., drowsiness, thirst, hunger, sexual desires (often).

177. *Touch* is but developed feeling, and may be considered as the feeling of animal life, being relative rather than organic. Its chief seat is the *skin*. Some hold that a sensation being given, there are certain proportionals (as

$\frac{1}{8}$ more for pressure), any differences less than which cannot be felt; also that these proportionals hold good whatever the amount of sensation: thus, the curve of feeling would be a logarithmic one; but this is not always, if ever, true, since differences of far less than $\frac{1}{8}$ can be detected between two sounds of moderate volume. We become aware of sensations of touch by pressure. They are of two classes: (1) *Emotional*: Soothing, Pungent, Tickling, Sexual, Painful, Temperature; (2) *Intellectual*: Plurality of points, Amount of pressure apart from muscular exertion. There are also certain *muscular sensations* partaking somewhat of the nature of touch: Exertion, Exertion with movement, Degree of exertion. Sensations of touch and muscular feeling combined are: Resistance, Weight and pressure, Hardness and softness (including elasticity, roughness and smoothness), and Extension—by which last we tell of Size, Distance, Direction, Situation, and Form.

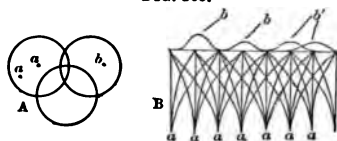
178. Allied to tickling are the sensations of a limb 'recovering from sleep' (not the prickling felt when it is moved); of the so-called 'funny-bone' at the elbow, being struck gently, (really, pressure upon the ulnar nerve); 'setting the teeth upon edge'; putting the feet upon a jarring, quickly vibrating body; of a Faradaic or interrupted electric current; itching; that preceding sneezing; &c.

179. Thermic sensations (of heat and cold) vary between 50° — 117° F. for *solid* objects, being keenest between 81° and 91° ; all other temperatures causing pain (including burning): a difference of 1° F. ($\frac{1}{8}^{\circ}$ F. ?) can be distinguished. The sensation varies greatly with the density of the object, increasing with it. Thermic sensations are almost confined to the skin.

180. If two objects touching the skin be placed very close together, there is only one impression perceived, as though there were but one object: in order to produce two impressions the points must be a certain distance away: this distance is termed the limit of tactile sensibility: it varies from $\frac{1}{88}$ —3 in. according to the part, being most acute at the tip of the tongue, then tip of fore-finger, most obtuse down the centre of the back,—in the limbs becoming

more acute near the extremity, in arm as 1 : 24, in leg as 1 : $8\frac{1}{2}$; hæmal surfaces are more sensitive than dorsal ones. The reason seems to be as follows: each nerve fibre splits up peripherally into a bunch of fibrillæ, which spread out so as to supply a certain area, which varies (usually about $\frac{1}{100}$ sq. in.). (1). Either the smaller these sensory circles and the more they intercalate, the keener and more accurate the touch: if one, two, or more points touch one circle, there is only one impression; if two circles, two; if an intercalated portion supplied by two (or more) nerves, one,—but a much more accurate knowledge of the spot;

FIG. 305.



Peripheral distribution of nerve-fibres. Two theories.

- A. Three sensory circles are seen. *a, a* points not separately distinguishable. *a, b* points separately distinguishable.
 B. *a, a* nerve-fibres splitting up into fibrillæ. *b, b* waves of excitation separately distinguishable. *b'* waves hardly or not distinguishable.

(2) or these circles may overlap each other to the extent of four or five deep in all parts, in which case two points of excitation must be separated by a sufficient space where there is little or no irritation, in order that two impressions may be perceived, and the distance may vary, diminishing with practice, which seems very probable. However, if the first and second fingers be crossed, and a pea placed between them, two impressions (i. e. as of two objects) are felt, so that the mind seems to judge of form by experience in the movements required to comprehend it. If a vibrating body touch the skin, and the vibrations occupy less than $\frac{1}{840}$ sec. each, the surface of that body seems smooth, so that tactile impressions last $\frac{1}{840}$ sec. A plentiful blood-supply seems essential to keen touch.

181. In pressure a difference of $\frac{1}{8}$ can be distinguished, $\frac{1}{8}$ of a grain is the minimum which can be felt. If muscular effort be involved, as in lifting (and usually in weighing) an object, a difference of $\frac{1}{17}$ is distinguishable.

182. All actions—muscular movements—need a guiding sensation, in order to produce any definite movement: this

is generally entrusted to sight principally, but also to the muscular sense, and more so to the skin. The influence of these sensations is sensori-motor, but slightly controlled by the mind, e. g. upon looking over a precipice, or from a tower, fear may be felt, although we may be, and *know* mentally that we are quite safe. Again, persons born deaf are usually dumb also, practically : they may make a noise, but no definite one.

183. The muscular feelings of exertion are due partly to the muscular sense, but *partly* also to the *skin surrounding the part moved*, especially over the tendons ; those who doubt the existence of the muscular sense attribute the feeling entirely to the skin. These sensations must be very acute, in order to regulate so accurately the muscular movements. Fatigue is probably chiefly due to the muscular sense. The muscular sense informs us of the strength, direction, distance, and rapidity of muscular movements, and of bodily equilibrium ; possibly also some knowledge of the position of parts, though this is chiefly due to the skin.

184. The four special senses—smell, taste, hearing, and sight (or vision), are but extremely delicate and highly developed modifications of touch. The following is an imperfect popular classification of the senses. (The numbers refer to the order in which they become dormant upon going to sleep.)

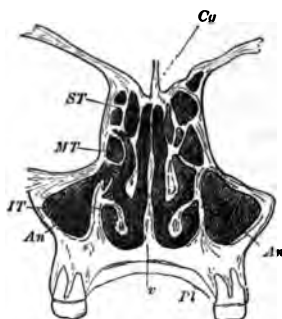
Molar or Dynamical	{ Tactile	Touch	5th
	{ Acoustic	Hearing	4th
Molecular or Chemical	{ Dialytic	Taste	2nd
	{ Catalytic	Smell	3rd
Intermolecular or Etheric	{ Thermic	Heat	
	{ Photic	Sight	1st

It is *possible* that some animals possess another sense, altogether absent, or else very rudimentary and (like its organ) unrecognized, in man, and this may be a magnetic one : hence the faculty by which dogs, &c., have made such long journeys, and by which birds, &c., migrate ; e. g. swallows, which not merely migrate by instinct at a certain time, but to the same nest a couple of thousand miles away.

185. *Smell*.—The seat of smell is the roof and the upper part of the walls of the nose,—the parts supported by the

ethmoid bone (including the upper and perhaps the middle turbinals). The nose consists of two cavities, the nasal fossæ, with complicate walls, and which open externally by the anterior nares or nostrils, and into the pharynx by the posterior nares. The roof of each fossa is formed by the cribriform plate of the ethmoid: the inner wall by the median ethmoid above, and the vomer below. Towards the front the septum is cartilaginous: the floor is formed by the maxillary and palatine bones: the anterior wall by the nasal bone and cartilage: the posterior wall, which is incomplete, by the sphenoid: the external wall by the lateral ethmoid and its two laminæ, the upper and middle turbinals, by the lower turbinal (a separate bone)—all three turbinals curving inwards and downwards—and by the superior maxillary. Several of the bones of the skull are, as before

FIG. 306.



Transverse vertical section of nasal fossa. (Seen from behind.)

Cg crista galli. *v* vomer. *Pl* palate. *An* antrum. *ST*, *MT*, *IT* superior, median, and inferior turbinals.

mentioned, hollowed out into cavities, 'sinuses,' or into smaller 'cells,' and many of these communicate by openings with the nasal cavities. The upper turbinal is short, and between it and the middle one is a groove, the superior meatus, connected with the posterior cells of the lateral ethmoid. Between the middle and lower turbinals is the middle meatus, which has two orifices, the anterior, or infundibular passage connected with the anterior ethmoidal cells, and the frontal sinus, and the other with the maxillary sinus or antrum. Between the inferior turbinated bone and the

nasal floor is the inferior meatus, into which opens the nasal duct : opposite its extremity behind is the mouth of the Eustachian tube. In the back part of the roof is an opening into the sphenoidal sinus of that side. In the floor a slight cul-de-sac is prolonged into the anterior palatine canal.

FIG. 307.



Outer wall of left nasal fossa.

st, mt, lt superior, middle, and inferior turbinated processes. *s, m, l* superior, middle, and inferior meatuses. *ss* sphenoidal sinus. *pe* posterior ethmoidal cells. *ae* anterior ethmoidal cells, &c. *a* antrum. *nd* nasal duct. *e* Eustachian orifices. *pn* posterior boundary of nasal fossa. *ap* anterior palatine canal. In A the orifices, which are underneath the processes, are indicated by dots; in B these processes have been removed in order to show the orifices.

The olfactory region is lined with the *pituitary*, or Schneiderian membrane, the rest of the cavities with the ordinary ciliated respiratory epithelium, except the external nostrils, which have a stratified squamous epithelium. The pituitary membrane is of a yellowish colour, and is lubricated by Bowman's glands, which are modified mucous glands, and it is supplied by pale or grey nerve-fibres—the olfactory

FIG. 308.



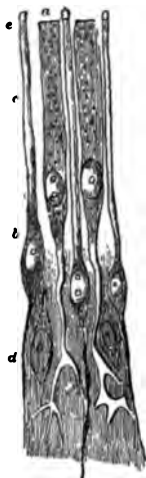
Nerve supply of the nares.

A septum. B outer wall. *o* olfactory lobe. *o'* olfactory filaments. *5 5'* branches of the fifth nerve. *sp* sphenopalatine ganglion. *c* cribriform plate of ethmoid.

filaments—which arise from the olfactory lobes, and pass through the cribriform plate. The pituitary epithelium consists of non-ciliated slender columnar cells, between which are scattered numerous filamentary rod-like cells, the olfactory cells : both kinds of cells have a nucleus in their

lower part, which is continued as a slender filament: the epithelial cell - continuations, branching and sometimes forming a delicate horizontal lamina, are connected with the subjacent connective-tissue, whilst the olfactory cell process is probably in continuation with an olfactory nerve filament.

FIG. 309.



Termination of olfactory nerves. (Man. After Schultze.)

a epithelial cell. *b* olfactory cell. *c* their peripheral rods, *d* their central filaments.

Upon the end of the olfactory cells is seen a jelly-like seam, which is either artificial, or represents the single 'hair,' or the ciliæ of some vertebrates. The cells of the marginal part of the olfactory region are both seamed and ciliated.

186. We smell in consequence of odorous particles impinging upon the ends of the olfactory cells, and there acting chemically and directly. Odorous bodies are usually volatile, and imperfectly oxidised: odours are perhaps due to oxidation. If a spot of odorous fluid be dropped upon water, the particles scatter quickly in all directions, so as to form a thin film. The sinuses are not sensitive to odours, but serve as reserve cavities for particles; $\frac{1}{13,000,000}$ grain of musk can be detected. Smells are of three kinds. (1) In sympathy with the lungs: fresh and close. (2) Odours proper: fragrant and fetid (not yet classified), (3) involving tactile sensibility; pungent.

187. *Taste*.—The seat of taste is situated in the *tongue* chiefly, the posterior $\frac{1}{3}$ of its dorsum, under the apex, $\frac{1}{4}$ in. wide along the edges, in parts of the palates, the anterior pillars of the fauces, and possibly a little in the pharynx. The sense of taste proper is conveyed to the brain by means of (1) the Glosso-pharyngeal nerve which chiefly supplies the posterior $\frac{1}{3}$ of the tongue, &c., and (2) the gustatory branch of the trifacial which chiefly supplies the anterior $\frac{2}{3}$ or $\frac{3}{4}$ of the tongue, &c. Many think that the gustatory filaments of the trifacial are derived from the chorda tympani branch of the seventh, or facial nerve, but even then their ultimate origin may be from the fifth, or possibly some filaments are derived from both. The nerves terminate generally in a plexus in the papillæ beneath the epithelium of the tongue; the ultimate connexion of the plexus with the epithelium is unknown,—possibly the fibrillæ are continuous with the deep ends of cells; some of them end in peculiar structures termed *taste-cones*, or *taste-buds*, which

FIG. 310.

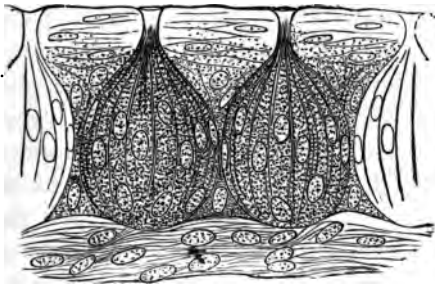
*Taste-buds.* (Rabbit. Engelmann.)

FIG. 311.

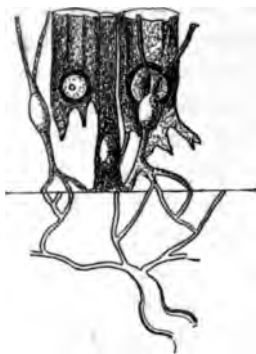
*Cells from taste-bud.*
(400 diameters.)

a cortical. b central cells.

are more especially found embedded in the stratified epithelium of the sides of the circumvallate papillæ: each is a minute roundish flask-shaped body, about $\frac{1}{300}$ in. long, and communicates with the fossa by a small opening—the gustatory pore—between the epithelial cells: each consists of two sets of nucleated cells, (1) the outer or investing cells flattened and pointed, (2) the inner or true gustatory cells, rod-like, having a cilium on the free end, and branched below, the branches communicating with the nervous plexus. Taste-cones are also found upon the fungiform papillæ, some

again on the free surface, whilst near the base of the tongue are five longitudinal rows, forming a rudimentary 'papilla

FIG. 312.



Termination of gustatory nerve (in a frog. After Engelmann). Two goblet cells, one columnar, and two forked cells are seen.

foliata.' The *filiform* papillæ seem to be connected with the sense of *touch* only.

188. Taste is a complex sense into which, besides taste proper, *smell* and *touch* enter. The *flavours* of food are due to *smell*: of this two popular proofs may be given (1) when the posterior nares are obstructed as in a cold, and (2) *during inspiration*, nearly all 'tastes' are taken away. When eating, a current of air is sent up the posterior nares during expiration, and thus particles, slightly different to odorous particles, impinge upon the olfactory nerves: the appreciation of flavours seems to be another instance of transferred sensation. Thus odours are perceived during inspiration (only), flavours during expiration (only); hence the in- and ex- spiratory jerks to intensify the respective sensations. Some bodies, e.g. cinnamon, possess a flavour, but no taste. Tastes are of three kinds. (1) In sympathy with the stomach, Relishes and disgusts; (2) tastes proper or simple, *sweet* and *bitter* only, probably; (3) tastes involving touch, Saline, Alkaline, Acid and Sour, Astringent, Fiery. The gustatory sensibility differs in kind in various parts; thus some articles, e.g. seasonings, are appreciated equally well by both parts of the tongue: astringents are perceived by the fore-part only: bitters and mineral acids almost entirely

by the posterior part: sweet and saline tastes by both, but most acutely by the fore-part: vegetable acids better along the edges. Some substances are appreciated in different ways by the two parts, e. g. chloride of potassium, in the anterior part cool and salty, in the posterior sweet; sulphate of soda, in the anterior salty, posterior bitter. Bodies, in order to be sapid, must, generally speaking, be soluble, and tastes are better perceived by rubbing the tongue against the palate, which process seems to be sometimes necessary. Different qualities are not detected with equal ease, thus sweet substances are not soon detected, whilst acid ones very readily are. One part of sulphate of quinine can be tasted among 1,000,000 parts of water. Taste is influenced by electric and other conditions.

189. *Hearing*.—The organs of hearing are the two ears, each of which consists of three parts, the external, middle,

FIG. 313.

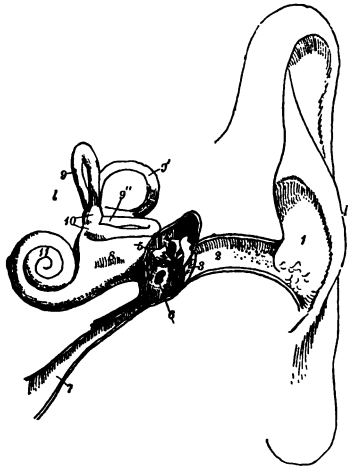


Diagram of the ear. (After Wilson.)

p pinna. t tympanum. l labyrinth. 1 concha. 2 meatus. 3 tympanic membrane. 4 the three ossicles, the stapes blocking up 5 the fenestra ovalis. 6 fenestra rotunda. 7 Eustachian tube. 8 vestibule. 9, 9', 9'' the perpendicular, oblique, and horizontal semicircular canals. 10 two of their ampullæ. 11 cochlea.

and internal ears: the two latter are hollowed out of the petrosal bone chiefly.

190. The external ear consists of a nearly immovable figured part, the pinna, supported by fibro-cartilage, and

from which passes inwards a canal, the meatus auditorius externus. The central hollow of the pinna is termed the concha, in the bottom of which is the canal mouth: the outer border of the pinna is termed the helix,—the ridge within, the antihelix,—the elevation in front of the concha, the tragus,—that just opposite, the antitragus: below the concha is a pendulous 'lobe,' peculiar to man; sometimes there is

FIG. 314.



Outer surface of right pinna.

h, h helix. t tip. fh fossa of the helix. ah antihelix. fa fossa of the antihelix. c concha. i tragus. at antitragus. l lobe.

FIG. 315.



Two ceruminous glands, magnified.

a little tubercular projection of the cartilage within the helix, representing the tip of the ear of animals. The surface of the canal walls is moistened by the ceruminous glands, which morphologically are modified sudoriparous glands. The outer part of the canal is furnished with hairs. Stretched across, and closing its inner end, is the membrana tympani, which is concave towards the canal.

191. The middle ear, tympanum, or drum, lies upon the inner side of the tympanic membrane, and consists of a hollow cavity. From its front passes a tube (about $1\frac{1}{2}$ in. long), the Eustachian, which opens into the pharynx, thus communicating indirectly with the open air: the pharyngeal opening is usually patent, but during swallowing is closed—the opposite opinion is also entertained. The tympanum is also connected with the mastoid cells. The greater part of the tympanic cavity and the Eustachian tube are lined with ciliated epithelium. Across the cavity is stretched a chain of small bones—the auditory ossicles—three in number.

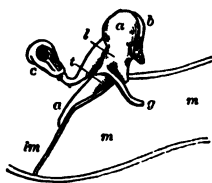
I. The malleus, or hammer, consists of a head and two

processes—the manubrium, or handle, and the processus gracilis. The handle is attached to the tympanic membrane, the other process to the cavity wall.

II. The incus, or anvil, is a bicuspid body. Into its concave head fits the head of the malleus; its shorter process is attached to the tympanic wall, whilst to the end of its longer process is soldered a minute osseous nodule, the os orbiculare, by many reckoned as a separate bone.

III. The stapes, or stirrup, whose head articulates with the os orbiculare of the incus,—its somewhat oval plate being attached to the fenestra ovalis.

FIG. 316.



The auditory ossicles in situ. (After Quain.)
a, *a* malleus. *g* its processus gracilis.
b incus. *c* stapes. *m*, *m* meatus
 auditorius externus. *tm* tympanic
 membrane. *t* line of action of tensor
 tympani muscle, *t* that of the laxator
 tympani.

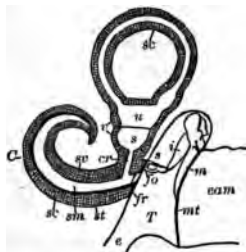
FIG. 317.



Auditory ossicles (?).
a malleus. 1 head. 2 handle. 3 pro-
 cessus gracilis. *b* incus. 4 short, and
 5 long processes. 6 orbicular process.
c stapes.

192. The internal ear or labyrinth, which is completely closed, consists of three portions, the vestibule, cochlea, and semicircular canals. The walls of the labyrinth are

FIG. 318.

*Diagrammatic section of the ear.*

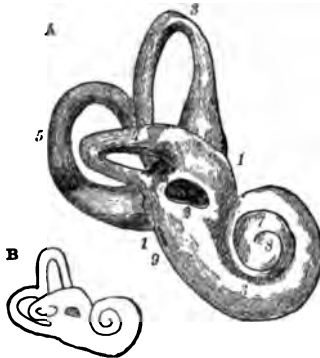
eam external auditory meatus. *mf*
 membrana tympani. *m* malleus.
i incus. *s* stapes. *T* tympanum.
e Eustachian tube. *fo* fenestra
 ovalis. *fr* fenestra rotunda.
C cochlea. *sv* scala vestibuli.
sm scala media. *sc* scala cochleæ.
st scala tympani. *cr* canalis
 reuniens. *v* vestibule. *u* utricle.
sc semicircular canals

very dense: they constitute the bony labyrinth, which is filled with a limpid watery fluid, the perilymph, in which is suspended (by means of fibrous bands) the membranous

labyrinth, the parts of which correspond pretty well to the bony ones: the membranous labyrinth is filled with endolymph.

193. The bony cochlea, or 'snail's-shell,' has running down its centre a pillar—the modiolus—round which a ridge—

FIG. 319.



Right osseous labyrinth (from outer side).

A magnified ($\frac{1}{2}$). B natural size.

1 vestibule. 2 fenestra ovalis. 3 superior semicircular canal. 4 external s. c. 5 posterior s. c. 6, 7 cochlea. 8 its summit. 9 fenestra rotunda.

FIG. 320.

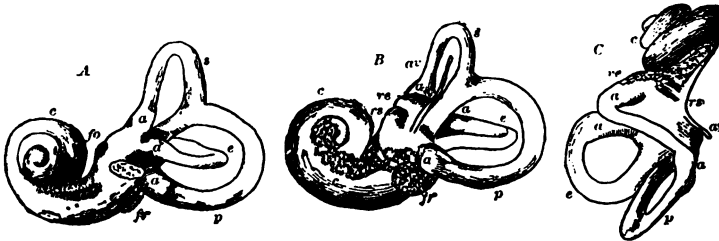


Section of osseous cochlea.

1, 1 modiolus. 2, 2 lamina spiralis
3 scala tympani. 4, 4 scala vestibuli.

the lamina spiralis—makes $2\frac{1}{2}$ spiral screw-like turns. From the limbus, or edge of this bony ridge, to the outer wall is stretched the canalis cochleæ, forming a membranous partition, which divides the tube of the cochlea into two parallel

FIG. 321.



Osseous labyrinth. (Henle.) Casts of interior.

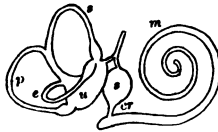
A left labyrinth from outer side. B right one from inner side. C left one from above. s, p, e superior, posterior, and external semicircular canals. a, a ampullæ. av aqueduct of vestibule. c cochlea. f tractus foraminosus spiralis. re fovea hemi-elliptica. rs fovea hemispherica. fo fenestra ovalis. fr fenestra rotunda.

spiral canals,—the upper, termed the scala vestibuli, communicates with the vestibule near the fenestra ovalis, or

foramen ovale, and the lower, the scala tympani, terminates at the fenestra rotunda, or foramen rotundum. Across both fenestræ are stretched fibrous membranes, continuous with the bone-periosteum: they are both close together, on the inner wall of the tympanic cavity. The two scalæ communicate at the cupola—the top of the modiolus, by a minute aperture, the helicotrema. The vestibule is the central portion of the internal ear: into it open the three semicircular canals by five openings (two mouths being united), each having a dilatation, or ampulla at one extremity. The canals are (1) an *external*, inferior, and horizontal; (2) a *superior*, vertical, transverse; and (3) a *posterior*, or oblique, vertical, and longitudinal: all three are nearly at right angles to each other: the non-ampullated mouths of 2 and 3 are united.

194. The membranous part of the ear consists of a vestibule, three semicircular canals, and the canalis cochleæ.

FIG. 322.

*Membranous labyrinth.*

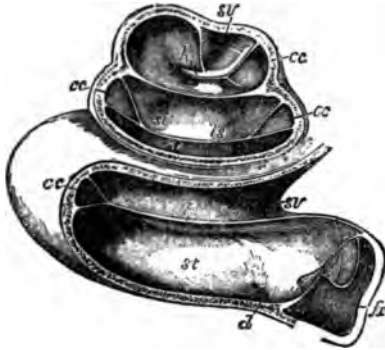
s, p, e superior, posterior, and external semicircular canals. u utricle. s saccule.
cr canalis reuniens. m canalis membranacea cochleæ.

The semicircular canals correspond exactly to the osseous ones (but are much smaller), each having an ampulla. The vestibule is separated by a membranous partition into two parts, (1) a smaller *sacculæ*, into which the canalis membranacea opens by a short duct—the canalis reuniens; (2) a larger *utricle*, into which the five mouths of the semicircular canals open: the utricle sends out a minute blind canal, which is joined by a minute canal from the saccule; thus both saccule and utricle are connected. In the endolymph of the saccule is suspended an otolith—a small mass of carbonate-of-lime particles, embedded in gelatinous matter, which suspends the otolith from the walls; another otolith is found in the utricle, and several very minute otoliths,

or otoconia, are found in the ampullæ, and semicircular canals.

The canalis cochleæ, or canalis media, is really double,

FIG. 323.

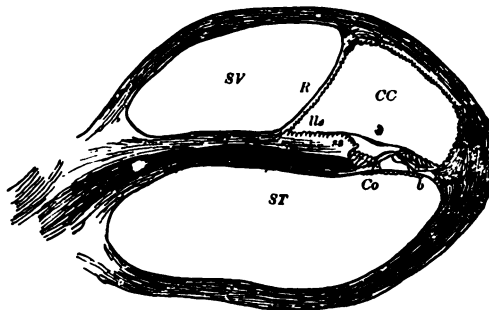


Section of left membranous cochlea.
(Child, somewhat dried.
-Reichert.)

fr fenestra rotunda.
d orifice of aqueductus cochleæ.
st scala tympani.
sv scala vestibuli.
le lamina spiralis.
cc canalis cochleæ.
h hamulus (the hook-like termination of the osseous lamina).

consisting of (1) a large upper canal, c. membranacea, scala media, or collateral passage, filled with endolymph, but ending blindly above; and (2) a very narrow lower one, the ductus auditorius, also containing endolymph. The upper wall of the canalis media is formed by Reissner's membrane, the

FIG. 324.



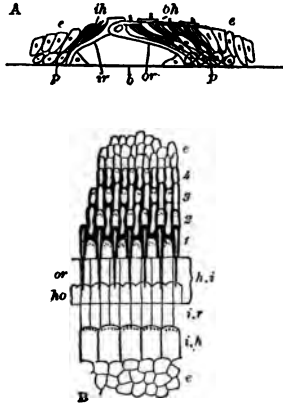
Section of a coil of the cochlea. (After Henle.)

ST scala tympani. *SV* scala vestibuli. *CC* canalis cochleæ. *R* Reissner's membrane. *lls* limbus laminae spiralis. *ss* sulcus spiralis. *Co* Corti's organ. *b* basilar membrane. *t* membrana tectoria. The cochlear nerve (shown dark) is seen running through the central lamina to Corti's organ.

lower by a stout basilar membrane, the partition by the membrana tectoria. In the ductus auditorius lies the *Organ of Corti*, which consists of (1) variously-shaped nucleated

cells, many of them bearing several stiff ciliæ-like filaments; (2) the rods of Corti, which are arranged in a double row, joined to each other at an angle, forming the arches

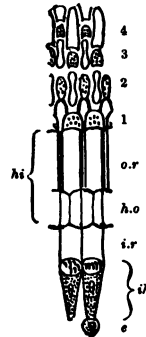
FIG. 325.

*The organ of Corti.*

A lateral view. B seen from above. (The membrana tectoria is removed.)

i.r inner rods. o.r outer rods. h.i heads of inner rods, shown as if transparent. h.o subjacent heads of outer rods. ih inner, and oh, 1, 2, 3, 4, outer hair-cells. p, p protoplasmic cells. e epithelium of spiral groove. b basilar membrane. The lamina reticularis is shown black in the upper part of B.

FIG. 326.



Elements of organ of Corti, more highly enlarged.

(Letters as before.)

of Corti: there are about 3500 (4500) outer, and 5200 (6000) inner rods, and they increase in length as they approach the apex of the cochlea (the outer always being the longest), being there twice, or more than twice the length of those at the base (about $\frac{1}{100}$ in.) Connected

FIG. 327.

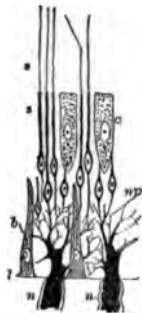
*Arch of Corti.*

o outer, i inner rod, both standing on the basilar membrane.

with the outer rods is a reticulated network over the hair-cells, the hairs of which project upwards through it; a rudimentary reticular membrane is also found surrounding the inner hair-cells, and arising from the heads of the inner rods.

The organ of Corti rests on the basilar membrane, and the fibrillæ of the rods (which have for the most part a fibrillated structure) seem continuous with the fibrillæ of that membrane. A nucleated protoplasmatic mass is found in connexion with the base of each inner and each outer rod, sometimes one also with the head of the inner rods; and there is always a rather large nucleiform body in the heads of the outer rods.

FIG. 328.



Auditory epithelium. (After Schultze.)
c columnar cells. *s* spindle-shaped hair-bearing cells. *h* the hairs. *b* basal supporting-cells. *l* limit of tunica propria. *n* nerves which break up into *np* the nervous plexus connected with the spindle-shaped cells.

FIG. 329.



Diagram showing the termination of the auditory nerve-fibres.
a axis-cylinder.

There is one row of inner hair-cells, and four rows of outer hair-cells; beneath the hair-cells are found protoplasmic cells, —perhaps nervous in function. The laminæ reticulæares are connected externally with intercellular tissue. The membrana tectoria overlies the whole structure, lying loosely upon it, reaching from the limbus to the outer epithelial cells of the basilar membrane (or to the outer wall?) in man.

195. The auditory nerve supplies the organ of Corti, parts of the saccule and utricle, and the three septa transversa, or cristæ acusticæ—small elevations (formed by wall-thickening) which project into the ampullæ. In the cochlea the nerve-fibres end in the 'ciliated' cells. The epithelium of the vestibule in general is nucleolated columnar, but in the parts supplied by the auditory nerve, there are scattered between the epithelial cells, other slender fusiform, or rod-shaped nucleolated cells, from which frequently projects a long stiff cilia or filament; these hairlets, or

auditory hairs, are found in the utricle and ampullæ; they are liable to split up longitudinally: basal supporting epithelial (nucleolated) cells project upwards among the other elements: the nerve-fibres below terminate in a plexus, and it is believed that the posterior ends of the rod-like cells are continuous with nerve-fibrillæ. Some think that the hairlets are borne by the columnar cells (one to each), and that the nerve-fibrillæ are continuous with the posterior ends of these (also one to each).

196. By the ear-apparatus we receive sound-impressions. Sounds travel at the rate of about 1130 ft. per sec. through atmosphere of 50° F.,—more quickly in a higher temperature, and through *denser* bodies. 'A sound' (i.e. its external factor) is a state of vibration of the atmosphere, (sound waves are horizontal): these waves pass down the external auditory canal, and strike upon the tympanic membrane, causing it to vibrate; this sets the chain of ossicles oscillating, and thus the fenestra ovalis is set in motion; this again conveys the vibrations to the perilymph, the perilymph to the membranous labyrinth and endolymph, the endolymph to the rod-cells, &c.; and these affect the nerve-fibrils, and so finally the brain.

197. The use of the pinna is to collect sounds, like an ear-trumpet. There are certain muscles in the tympanum which regulate the volume of sounds, some increasing, others diminishing them. The Eustachian tube prevents undue pressure upon the membrana tympani. The foramen rotundum supplements the f. ovale. The otoliths intensify (or damp?) impressions. The use of the semicircular canals is three-fold, informing us of *the direction* (1) *of sounds*, (2) *of the movements of the head upon its axis*, thereby subserving the support of the bodily equilibrium: when injured vertigo results: (3) *of the general movements of the head*. The three canals, being nearly at right angles, are supposed to give us ideas of *space* in its three dimensions. There being only three canals, the indications of direction are not usually very accurate: visual accuracy herein is due to the somewhat analogous eye-muscles being supported by the minutely divisible area of the retina. When the head is moving

round, the endolymph, tending to remain stationary,—in the other two cases, the external impact,—causes a wave of pressure against the hair-filaments, &c. The first-named capacity, denied by some, is, I think, undoubtedly possessed by the ear, apart from what may be termed acoustic perspective (as exemplified by Ventriloquism), possession of two ears (though highly useful), and (mental) experience. The function of the cochlea is to appreciate the *qualities* of sounds. The sacculæ and utricle seem (in man) chiefly to subserve the cochlea and canals.

198. Every *musical* sound is found to consist of a powerful fundamental tone, accompanied by several lighter overtones, partial tones, or harmonics, of a higher pitch than the fundamental one, and having their vibrations as 2:1, 3:1, 4:1, &c., with respect to it, practically up to 6:1, the higher overtones being too weak to be noticed. Several of the overtones are usually absent, and thus the order of those present is irregular. Upon the number, order, and relative intensity of the overtones depend the different qualities (timbre) of the sounds produced by different musical instruments; thus, the harmonics with an open pipe are 2, 3, 4, 5, &c.,—with a closed pipe 3, 5, 7, &c.: the fundamental tone, when alone, sounds clear but inanimate. The different vowels are caused by the mouth being tuned to different pitches, thus reinforcing some partials, damping others. The majority of musical instruments are upon two principles: A, strings; B, pipes subdivided into (1) flue-pipes and (2) reed-pipes. But nine methods of producing musical sounds may be noticed: vibrations of strings, rods, plates, bells, membranes, reeds, columns of air, flames, and electro-molecular changes (phonograph). The vocal-cords are free membranous reeds; the lips also in playing brass instruments. With strings, the frequency of vibration varies (1) *inversely* as length and as $\sqrt{\text{mass or weight}}$, (2) *directly* as $\sqrt{\text{tension}}$: thickness unimportant if tension $\propto$ sectional area. Harmony, consonance, or concord is dependent upon (1) a simple ratio (numerical ratio of vibrations) existing between the notes; the simpler the ratio, the more perfect (theoretically) the harmony or concord, but not always the more agreeable

to the ear; thus 3rds and 6ths are the most pleasant, then 5ths and 4ths, then octaves; (2) the coincidence (and relation) of harmonics: (N.B. Resultant Tones). Beats, caused by imperfect unison (and so, slowly alternating vibrations of fundamentals or partials), are the chief element of dissonance. The following are practically the harmonics of an octave, taking C as the base note, and as the denominator of the fractions. (The asterisks indicate the black notes of the piano, which serve as both flats and sharps; the ratios marked are those of the flats, which are the simpler. I believe that $\frac{7}{4}$ is the ratio usually appreciated as a minor 5th.)

	C	*	D	*	E	F	*	G	*	A	*	B	C
	1	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{5}{3}$	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{7}{4}$	$\frac{8}{5}$	$\frac{9}{4}$	$\frac{10}{3}$	$\frac{11}{2}$	$\frac{12}{5}$	2
Tonic or unison		minor 2nd	2nd	minor 3rd	major 3rd	4th	minor 5th	5th	minor 6th	major 6th	minor 7th	major 7th	octave

Every key really requires 21 notes to the octave, (but if the 12 keys were taken many would coincide); thus for C—

C	C [#]	^b D	D	D [#]	^b E	E	E [#]	^b F	F	F [#]	^b G	G	G [#]	^b A	A	A [#]	^b B	B	B [#]	^b C	C	
1	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{5}{3}$	$\frac{5}{3}$	$\frac{5}{4}$	$\frac{6}{5}$	$\frac{6}{5}$	$\frac{7}{4}$	$\frac{7}{4}$	$\frac{8}{5}$	$\frac{8}{5}$	$\frac{9}{4}$	$\frac{9}{4}$	$\frac{10}{3}$	$\frac{10}{3}$	$\frac{11}{2}$	$\frac{11}{2}$	$\frac{12}{5}$	$\frac{12}{5}$	2

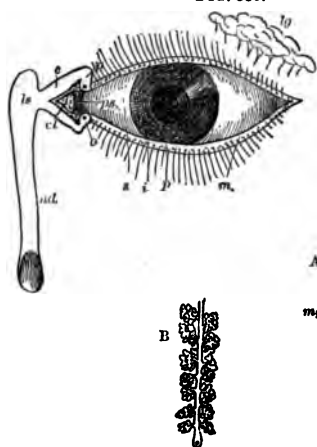
Pianos are very imperfect, since C $\sharp$ and $\flat$ D, &c., are not really the same note ($x : x\sharp :: 24 : 25$, $x : \flat x :: 25 : 24$), hence one advantage in a violin. The human ear can detect differences much smaller than semitones. The range of notes appreciated as musical sounds by the ear varies, usually about eight octaves 41·25—4752 vibrations per sec., 8—73,000 being the reported extremes. Sounds have three qualities. (1) Pitch, dependent upon the length (varying inversely with it, and so, directly as the frequency) of the aerial or sound-wave. (2) Intensity, upon its height. (3) Quality, upon its shape. The effects of music depends upon the sweetness, intensity, waxing and waning, volume: pitch, time, melody, harmony and discord; timbre, &c.

199. The rods of Corti are supposed to be the great agents of the cochlea. Some believe that different rods (or groups of rods) are attuned to different notes, and that these are affected by the influence of *consonance*, by which, if a body be caused to vibrate, all neighbouring bodies, under similar conditions, also vibrate, e.g. if a string of a

harp be struck, the corresponding string of another harp in the room will vibrate : but this I think somewhat improbable in the case of Corti's rods, which, besides other reasons (e.g. *absent in birds* ; the inner and outer rods not corresponding), are too uniform in length, and I prefer *pro tem.* to consider it an open question as to how we appreciate either pitch or harmonies. N.B.—The basilar membrane may be considered as a connected series of parallel fibres, radially tense, about twelve times as long at the hamulus as at the other extreme—thus giving about *twelve* octaves. (The Arches of Corti only vary some $2\frac{1}{2}$ times.) Filling up the octave with seven, twelve, or even twenty-one notes, seems to be very arbitrary,—the intervals being of several different values ; though long habit has rendered us more or less indifferent to the defects, e.g. the smaller intervals, 3—4, 7—8 in the major scale, 2—3, 7—8 in the ascending, and 6—5, 3—2 in the descending minor scale ; twelve notes or so, in most instruments, being made to do duty for nearly 200 in each octave,—hence the chief cause of music being written in different keys. The physiological-æsthetics and the mathematics of musical harmonies, &c., are very complicate, and but little understood.

200. *Vision or Sight.*—The visual apparatus consists of two eyeballs, with attached muscles, and other appendages. Each eyeball is situate in its orbit, and is surrounded by

FIG. 330.



Left eye. Semi-diagrammatic view.

- p* pupil.
- i* iris.
- s* sclerotic.
- lg* lachrymal gland.
- m* orifices of Meibomian glands.
- ps* plica semilunaris.
- cl* caruncula lachrymalis.
- pp* puncta lachrymalia.
- c* lachrymal canaliculi.
- ls* lachrymal sac.
- nd* nasal duct.

A portion of eyelid, inner surface.

ld orifices of lachrymal ducts.

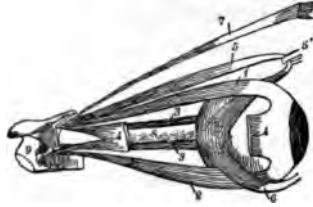
mg Meibomian glands.

B part of a Meibomian gland magnified.

cushions of fat. The eyeball is rather spheroidal; its diameters are, upon an average, antero-posterior .95 in., vertical .95 in., horizontal 1 in. It is of pretty uniform size, though the cornea, and the fissure between the eyelids, both vary. In front it is protected by the two eyelids, and indirectly by the eyebrow. The eyebrow is moved by several muscles, and is partly covered by hair. The eyelids are supported by fibro-cartilage, and are closed by an orbicular muscle; a levator palpebræ muscle also supplies the upper lid, lifting it up. Along the outer edges of each lid is a row of hairs, the cilia, or eye-lashes. At the outer upper angle of the orbit is the lachrymal gland, which secretes the tears, which ordinarily serve for the lubrication of the conjunctiva. Structurally it resembles a salivary gland, and possesses secretory or gland capillaries: it pours out its secretion by several ducts (about 12 altogether), a small anterior portion is separated from the main gland. In winking, the eyelids close, and the eyes converge (and turn upwards) in order to wash the surface with the tears: this movement also draws the tears into the lachrymal sac, by a pump-like, sucking action; hence one cause of blinking when weeping. There is also a small set of glands, the Meibomian follicles, which empty along the inner free margin of the eyelids: they secrete an oily fluid which prevents the overflow of the tears: structurally they are saccular follicles, and are modified sebaceous glands. Each consists of a nearly straight tube (two rarely uniting), with numerous compound follicles down the sides. Behind these are other very minute racemose glands. Near the canthus, or inner corner of the eye, are two small perforations, the puncta lachrymalia, one on the edge of either lid: by these the tears enter and pass down two canaliculi into a lachrymal sac, thence by the nasal duct into the nose. At the canthus is seen a small reddish spongy mass, the caruncula lachrymalis, at the edge of which is a fold of smooth membrane, the plica semilunaris; this fold is the vestige of a third eyelid (membrana nictitans), more developed in many vertebrates, especially birds of prey. The muscles which move the eyeball are six in number, and are arranged in three antagonistic pairs: they are attached

to the sclerotic coat; (1) superior rectus or attollens; (2) inferior rectus; (3) internal rectus, or adductor; (4) external rectus, or abductor; (5) superior oblique, or trochlearis, the tendon of which passes through a tendinous pulley attached to the frontal bone: it turns the eye outwards and downwards; (6) the inferior oblique turning it outwards and

FIG. 331.

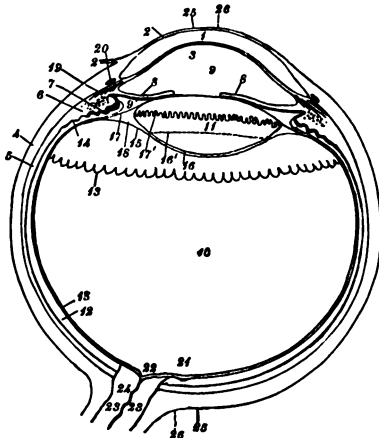
*Muscles of the eyeball.*

1 superior rectus. 2 inferior rectus. 3, 3 internal rectus. 4, 4 external rectus, partly dissected. 5 superior oblique. 5' its pulley. 6 inferior oblique. 7 levator palpebrae. 8 optic nerve. 9 portion of sphenoid bone.

upwards. One function of the oblique muscles is to act as substitutes for the superior and inferior recti, when the eyes are moved much to either side, and so these latter muscles rendered useless. The corresponding muscles usually act together, but generally the horizontal recti of both eyes act inversely, inner ones together also (as in near vision), and the outer ones: rarely, the eyes can move independently to a very slight degree, e. g. sometimes in looking through field-glasses.

201. The eye, roughly speaking, possesses three coats, the

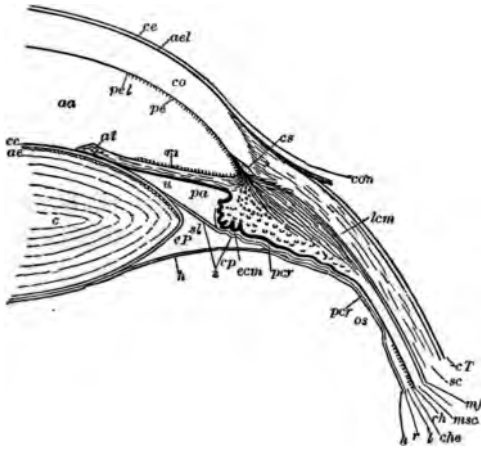
FIG. 332.

*Diagrammatic transverse section of right eye. 2.*

1 cornea. 2 its conjunctival layer. 3 its posterior elastic layer. 4 sclerotic. 5 choroid. 6 ciliary processes. 7 uvea. 8, 8 iris. 9 anterior, and 9' posterior chambers of aqueous humour. 10 vitreous humour. 11 crystalline lens. 12 retina. 13 ora serrata. 14 ciliary portion of retina. 15 hyaloid membrane. 16 its posterior layer. 16' line of its attachment to lens. 17 its anterior layer—the suspensory ligament of lens. 17' line of its attachment, undulating because of the ciliary processes. 18 canal of Petit. 19 ciliary muscle. 20 canal of Schlemm. 21 fovea centralis. 22 colliculus, where 23 the optic nerve enters. 24 arteria centralis retinae. 25, 25 points in the optical axis, 26, 26 in the visual axis.

sclerotic membrane, tunica vasculosa, and retina, and contains two chambers filled with fluid,—the chambers of the aqueous and the vitreous humours, between which is a lens, the crystalline lens. An adventitious tunic, tunica vaginalis

FIG. 333.



Diagrammatic section of part of the eye.

ae corneal epithelium. ael anterior elastic layer. con conjunctiva going off. co cornea. pel posterior elastic layer. pe posterior epithelium. aa, pa anterior and posterior chambers of aqueous humour. aa, ri annular and radiating fibres of the iris. c crystalline lens. cc its capsule. cc its epithelial layer, anterior surface. lcn, ccm longitudinal and circular fibres of ciliary muscle. cs canal of Schlemm. h hyaloid. sl suspensory ligament. s zonule of Zinn. cP canal of Petit. cp ciliary process. per pars ciliaris retinae. os ora serrata. v chamber of vitreous humour. cT capsule of Tenon. sc sclerotic. mf membrana fusca. msc membrana supra-chorioida. ch choroid. che choroidal epithelium. b bacillary layer. r retina.

oculi, or capsule of Tenon, surrounds most of the eye, being attached loosely to the sclerotic; it consists of two membranous layers, lined by a squamous epithelium: between it and the sclerotic is a lymph-space.

202. The *sclerotic* membrane forms an external tough fibrous capsule, consisting chiefly of white fibres, and for the most part is of a rather opaque white colour, being vulgarly called the 'white of the eye.' In front it becomes abruptly transparent, forming a circular patch, the *cornea*, which covers the 'coloured portion' of the eye. The posterior surface of the cornea is the larger, the sclerotic overlapping it at their juncture, where the iris projects, and where, near the inner surface, is a minute ring-like venous canal, the canal of Schlemm. The cornea serves as a window for the admission of light, and forms a concavo-convex lens: it is rather more convex than the rest of the sclerotic. In making a section of the cornea, we have (1) an external stratified epithelium; (2) an anterior elastic layer, not very distinctly marked off from

(3) a thick fibrous layer, the fibres of the alternate strata of which are at right angles, and have numerous flattened, branched, intercommunicating cells among them; (4) a posterior elastic layer; (5) a posterior epithelium, perhaps absent in the centre, but spreading backwards over the iris. The eyelids are lined by a membrane, the *conjunctiva*, which is reflected over the anterior surface of the eye, its epithelium becoming continuous with the external epithelium, and its subjacent layers passing into the anterior layers of the cornea. The posterior elastic layer and epithelium constitute the membrane of Demours or Descemet: the elastic layer divides posteriorly into three sets of fibres, which pass to the iris, choroid, and sclerotic, the former of which runs among the fibres of the iris, forming the pillars of the iris, termed from their appearance the *ligamentum pectinatum iridis*. These pillars are covered with epithelium, but the interspaces are not, and these latter communicate with the smaller venous spaces of Fontana near to Schlemm's canal, and perhaps *with it*; thus the aqueous humour communicates with veins. The *ciliary muscle*, consisting of non-striated fibres, also attaches the sclerotic to the choroid: its inner fibres (nearest the iris) run circularly, forming the ciliary muscle, (formerly termed the ciliary ligament); the rest of the fibres radiate backwards from a tendon attached to the sclerotic. The circular fibres have been found hypertrophied, the radiating ones atrophied in the hypermetropic (far-sighted) eye: the opposite in the myopic (near-sighted) one. The ciliary muscle is under the control of the motor oculorum nerve, and is a remarkable and exceptional instance of non-striated fibre being under direct voluntary control.

203. The middle coat, or *tunica vasculosa*, is a highly vascular membrane, partly lined by an epithelium. It is divisible into two parts, (1) a larger part—the *choroid*—lining the sclerotic for the most part: between it and the sclerotic is a delicate connective-tissue layer, the *membrana fusca*, which lines the sclerotic, and another similar one, the *membrana supra-choroidea*, which covers the choroid, and between these are lymph-spaces, lined by an epithelium; (2) a smaller

anterior part, the *iris*. The *m. vasculosa* consists of connective tissue, and numerous blood-vessels which form a dense network: its inner part, the so-called membrane of Ruysch, is formed mainly by the capillaries; the arteries and veins run (in a rather curious manner) in the outer part,—these and the capillaries form several very pretty patterns. Upon the inner side of the membrane of Ruysch is that of Bruch, which is almost structureless. Among the fibres of the *m. vasculosa* are branched cells, loaded with pigment, the nuclei

FIG. 334.



Blood-vessels of the choroid, &c. (Arnold.)
a capillary network of choroid. *b* line of the ora serrata. *c* arteries supplying the ciliary processes *d*, and passing into the iris *e*. *f* capillary network of the inner part of iris.

FIG. 335.

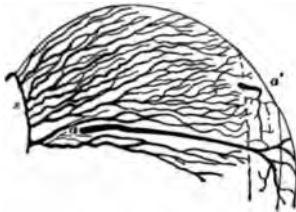


Capillaries of the choroid. (Sappey 39.)

being left clear. The cells of the epithelium are flattened, and hexagonal: opposite the choroid, they form a single layer, which properly belongs to the retina; but opposite the iris, they are stratified (and roundish), forming the *uvea*: these cells, like the branched ones, are loaded with a dense very dark-brown pigment (nuclei clear): in Albinoes, the pigment is absent. Just before the choroid passes into the iris it forms about 60 ray-like elevations, the *ciliary processes*, of two sizes, highly vascular, and

varying in size according to the degree of blood engorgement: their appearance forms the zonule of Zinn. The iris is continuous with the choroid, and forms a circular curtain, which depends into the cavity of the aqueous humour, and lies close against the crystalline lens, so that it is stretched across the eyeball; it has, nearly in its centre, a fairly circular contractile aperture, the *pupil*, which externally

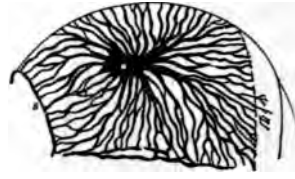
FIG. 336.



Arteries of the choroid and iris.
(After Arnold.)

s part of sclerotic remaining. *a* a long ciliary artery. *a'* an anterior ciliary artery.

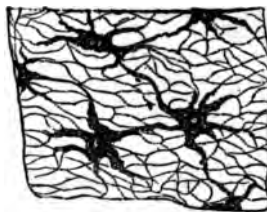
FIG. 337.



Veins of the choroid. (After Arnold.)
s part of sclerotic remaining.

appears to be black, and is slightly to the inner side. The colour of the iris is due, in black, brown, and grey eyes to the branched pigment cells, which here are of different shades, from yellow to very dark brown, and more or less numerous; but in blue eyes, these cells are absent, the blue colour being due to the black uvea behind the semi-trans-

FIG. 338.



Choroidal ramified pigment cells. (Kölliker.)

parent iris. The use of the pupil is the admission of rays of light, and its size varies, according to the amount of light (and with different individuals), from $\frac{1}{8}$ — $\frac{1}{10}$ in. diam.,—the size varying *inversely* as the amount of light: this is effected by two sets of non-striated muscular fibres in the iris (1) a circular, or annular set, the sphincter, round the

pupillary margin, which diminish the aperture; (2) a radiating set, the dilatator, which run all across from the pupillary to the external margin, for dilating the pupil: some of these seem to become continuous with the circular fibres. The circular set are under the control of the 3rd pair of nerves, the radiating fibres under the Sympathetic.

204. The *retina* is the delicate inner coat, composed of nervous elements, supported by and intermingled with areolar ones. It is divisible into (A) an outer layer, the so-called 'choroidal epithelium,' which should upon developmental

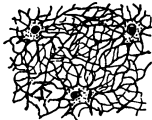
FIG. 339.

*Pigment epithelium.*

a cells with intercellular substance. *b* a cell seen sideways with minute effects extending inwards. *c* a cell still in connexion with the rods.

considerations be regarded as part of the retina, and may be termed the retinal pigmentary layer; and into (B) an inner thicker layer, the retina proper, which is divisible into seven layers, differently named by different authors; passing outwards, these are (1) a layer of nerve-fibres; (2) a ganglionic layer, consisting chiefly of multipolar nucleated ganglionic nerve-corpuscles, having ramified processes connected with the nerve-fibres, &c.; (3) the internal granular, or inner molecular layer; (4) internal nuclear layer; (5) external granular, or outer molecular layer; (6) external

FIG. 340.

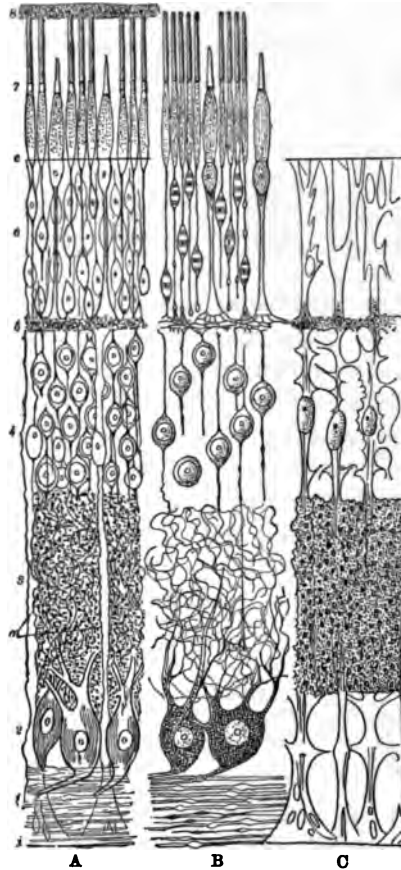


Branched cells with uniting fibrous felt-work from outer molecular layer.
(Horse.)

nuclear layer: its cells are granular and nucleated, and those connected with the rods are transversely striated, there being generally two discs of a clearer, less refracting material; (7) the bacillary layer, or Jacob's membrane, consists of rods and cones, placed vertically, their free ends resting upon the pigmentary epithelium, their bases connected indirectly with the nerve-fibres of (1) by means of delicate fibrils which form plexuses, and have nerve-cells on their course: the cones communicate more

directly than the rods; each cone is ultimately connected with *several*, each rod with but *one* axis-cylinder. The connective-tissue elements are unimportant physiologically, only serving to support and hold in place the nervous ones; sometimes they appear as vertical fibres running through

FIG. 341.



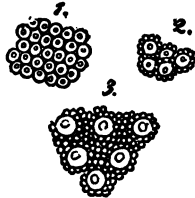
Diagrammatic section of the retina.

A general view. B nervous elements. C connective-tissue elements.
 i membrana limitans interna. 1 layer of nerve-fibres. 2 layer of nerve-cells. 3 inner molecular layer. 4 inner nuclear layer. 5 outer molecular layer. 6 outer nuclear layer. e membrana limitans externa. 7 bacillary layer of rods and cones. 8 pigment-epithelium cells. m two Müller's fibres. Three Müller's fibres are seen in C.

the retina, forming Müller's fibres. The bacillary layer is considered by many not to be true nervous tissue. The

rods are far more numerous than the cones, which are interspersed among them, rather scantily near the circum-

FIG. 342.

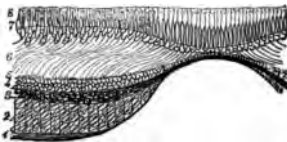


Outer surface of bacillary layer. (Kölliker.)

- 1 at macula lutea consisting of cones only.
2 near macula, a single row of rods intervening.
3 from retina mid-way from centre, rods predominating.

ference, but more and more plentifully nearer the centre of vision; upon an average about four rows of rods separate any two cones. In the centre of the retina behind (i. e. in the axis of vision) is a transverse yellowish patch, the macula lutea, or *yellow spot* of Sömmering ($\frac{1}{12} \times \frac{1}{80}$ in.), in the middle of which is a small depression, or pit, the *fovea centralis*. In the yellow spot the cones are separated by one circle of rods; in the fovea the rods are absent, the bacillary layer being represented by cones only (about 2000), which are here smaller and longer than usual; the nerve fibres of (1) are also absent, being probably represented by delicate fibrils among the ganglionic processes of (5); and all the layers, except (6), are rudimentary,

FIG. 343.



Diagrammatic vertical section through the macula lutea and fovea centralis.

- 1 nerve fibres. 2 ganglionic layer. 3 inner molecular. 4 inner nuclear. 5 outer molecular. 6 outer nuclear. 7 bacillary layer. 8 pigment cells.

FIG. 344.



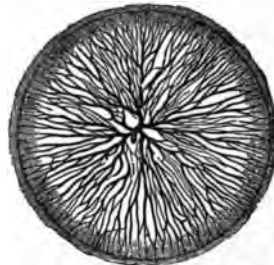
A rod and cone.

- a rod. b cone. c membrana limitans externa.

and the fibres in (6) sloping. The cones are (except in centre) shorter than the rods, but stouter, diam. of cones

$\frac{1}{4000}$ — $\frac{1}{7000}$ in., of rods $\frac{1}{8000}$ — $\frac{1}{14000}$. Both rods and cones consist of two parts or segments. The outer segments of both seem inclined to split up into transverse discs; those of the rods (and cones probably) also possess longitudinal grooves. The inner segments are divisible into two parts—that next the outer segment possessing longitudinal fibrillæ around it—the inner one being granular. The fibrillated portion is in the rods $\frac{1}{3}$, in the cones $\frac{2}{3}$ of the length of the inner segment, and in some animals this part of the cones possesses at its outer end a variously-coloured (red to green) globule. The cones (except those of the fovea) are always by far the shorter, and have their inner portion bulging. The rods project into the choroidal epithelium, the cells of which send filamentary processes for some distance between the ends of the rods. The optic nerve enters the eye at the back, about $\frac{1}{8}$ in. to the inner side of the centre (fovea centralis), at the optic pore; it then spreads out to form layer (1): it has been calculated that there are 250,000 fibrillæ in the optic nerve. The retinal artery enters along

FIG. 345.

*Retinal artery with its ramifications.* (Kölliker.)

with the optic nerve, and sends out its ramifications among the two inner layers: the veins also leave at the same point. The bacillary layer is absent at the optic pore. The retina, as such, terminates in front close behind the ciliary processes; its scalloped border forms the appearance termed the ora serrata; it there passes into a single layer of elongated nucleated cells, constituting the pars ciliaris retinæ, which reaches to the tips of the ciliary processes.

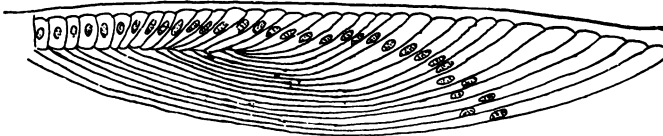
205. The *vitreous humour* fills the greater posterior

chamber of the eye (about $\frac{1}{2}$ of the eye). It is enclosed in a delicate membrane—the hyaloid membrane—which sends laminated processes of extreme tenuity into its interior, dividing it into about 180 radiating compartments; sometimes the fluid seems to be enclosed in numerous concentric capsules; it is probably enclosed in large cells. From the optic pore to the back of the lens runs a minute central canal—that of Stilling. The hyaloid membrane is attached to the retina, and in front to the lens.

206. The *aqueous humour* (.986 water) is bounded in front by the cornea, behind by the lens: it fills the small anterior chamber of the eye. It is itself incompletely divided by the iris into two communicating cavities, its anterior and posterior chambers, the latter being very small,—the iris generally, as it were, gliding for the most part upon the lens.

207. The *crystalline lens* is transparent and biconvex (the posterior surface being the more convex), and is about $\frac{1}{8}$ in. diam., $\frac{1}{16}$ in. thickness. It consists of a tough, structureless capsule, and of numerous fibrous layers increasing in density one within another, like an onion, and composing the body of the lens. Within the capsule and lining it ante-

FIG. 346.

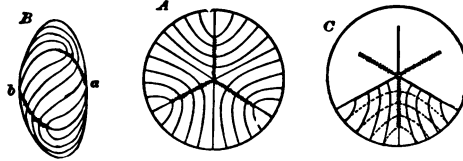


Section of part of crystalline lens of Rabbit. Showing the transition of the epithelium into lens-fibres. (Babuchin.)

riorly is a layer of cells, which passes gradually into the fibre-cells at the margin. The fibres of the layers are arranged in a radiating manner: in man they are arranged upon a tripolar plan; in the foetus the tripolar is simple, but in the outer layers of the adult each branch or pole near its origin divides into three on the anterior surface,—whilst the posterior surface is rather more irregular, there being nine to sixteen radii. The poles of the front and back sides alternate. The fibres extend from front to back; they

are really elongated cells, each containing a granular nucleus, and their edges are serrated or toothed, and so fit firmly into

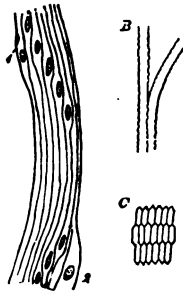
FIG. 347.



Fetal crystalline lens. Showing the course of the fibres.

A front view, showing the three poles. B lens seen edgewise: *a* anterior, and *b* posterior surface. C front view: the lens is supposed to be transparent: the dotted lines indicate the posterior poles, and the course of the fibres behind.

FIG. 348.



Fibres of the crystalline lens.

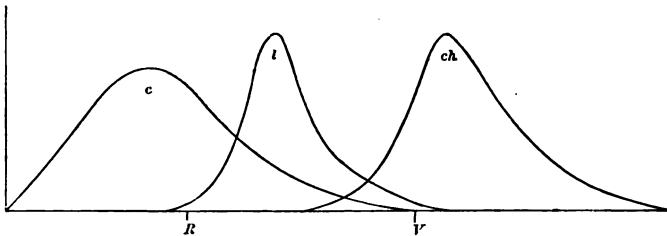
A shown edgewise, showing 1 the nuclei of the nuclear zone, and at 2 a fibre seen from before. B two fibres showing how they interlock. C transverse section of fibres.

each other behind: the fibres are 6-sided. The lens is suspended by means of the hyaloid membrane behind, and by the suspensory ligament—the zonule of Zinn, in front. The hyaloid near the ora serrata sends off this ligament as a process, which runs from the ciliary processes to the anterior edge of the lens, there becoming continuous with the anterior part of the capsular layer. Between the suspensory ligament and hyaloid membrane is a ring-like space, the canal of Petit, which appears sacculated in front,—the suspensory ligament undulating.

208. Light is analogous with sound, inasmuch as it is produced by vibrations of varying intensity and frequency, but light is produced by etherial waves, whilst sound is produced by aerial ones: light-waves are perpendicular, the particles moving transversely from side to side: sound-waves are horizontal, the particles moving vertically up and down,

as with water. Light travels at the rate of 186,300 miles per second. Colour depends upon the frequency of the waves: crimson has the fewest waves, and is the least refrangible colour,—from about 392,000,000 (435, m. ?) waves per second; violet the most frequent and refrangible—up to about 754,000,000 waves per second. Colours vary according to their (1) intensity; (2) hue, the amount of admixture with another colour on either side; (3) saturation, the amount of colour as compared with the white light mixed with it; in the spectral colours there is no white light. The tone of a colour depends upon the amount of white (or light) mixed with it; if white (i. e. much light), the tones are spoken of as tints; if black (little light)—

FIG. 340.



Curves of calorific (*c*), luminous (*l*), and chemical (*ch*) intensity in the solar spectrum.
R red. *V* violet.

shades. Etherial waves convey three properties, heat, light, and electricity: heat is the least refrangible, electricity most so.

209. The duration of an impression upon the retina varies from $\frac{1}{10}$ sec. upwards, generally about $\frac{1}{8}$ sec. Yellow is the most intense colour, and its impression lasts the longest: green comes next, then orange and blue, lastly red and violet. The consequence of duration of impressions is that if very frequent ones be made, as by a revolving disc of colours or patterns, e.g. a thaumatrope, they are not perceived as being distinct and separate, but blended together; if a toothed wheel revolves very rapidly (less than $\frac{1}{10}$ sec. per vibration), the margin seems to be smooth (instead of den-
 tated), and also stationary. A slowly revolving screw would appear to travel. A person in a dark room would almost

instantaneously perceive a spark, because there would not be any previous impressions hindering. A difference in illumination—the amount of light thrown upon an object—of about $\frac{1}{80}$ can usually be distinguished,—from $\frac{1}{88}$ — $\frac{1}{120}$ in different persons. With average sight, objects $\frac{1}{408}$ in. diam. can be seen as having distinct outlines, $\frac{1}{840}$ in. diam. can be seen, but not thus distinctly, lines $\frac{1}{4800}$ in. in breadth are visible: glittering objects, as a particle of gold dust, $\frac{1}{1125}$ in. diam., can be seen.

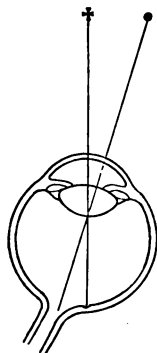
210. Light falls upon the cornea, then passes through the pupil of the iris, and falls upon the retina, where it in some manner seems to become converted into a centripetal nerve-current. In passing through the eye, the rays of light converge, being refracted three times; (1) upon striking the dense convex cornea; (2) upon falling upon the dense convex anterior surface of the lens; (3) in passing off from the convex posterior surface of the lens into the less dense vitreous humour (the thickness of the cornea is ignored, &c.): consequently the rays come to a focus before reaching the retina, and thus the images of all objects upon the retina appear *inverted*. The iris, through the action of light upon its non-striated fibres (indirectly?) regulates the amount of light admitted, by diminishing or enlarging the pupillary opening. Another function of the iris is to intercept the outer peripheral parts of the field of vision, and which would be indistinct through spherical aberration. The different density of the various parts is so arranged that, whilst allowing of refraction, it prevents the dispersion of light—chromatism, which causes objects to appear fringed with colours,—and the eye is thus rendered achromatic. Again, the structure of the crystalline lens, more and more dense from margin to centre, counteracts spherical aberration: increase of curvature near the central part would also, and *perhaps* does produce the same effect. The chief use of the choroidal pigment is to absorb the rays of light (black absorbing light), which would otherwise become reflected and interfere with vision.

211. Light is perceived by means of the bacillary layer, and not directly by the nerves, as appears from the following.

FIG. 350.



FIG. 351.

*Explanation of preceding diagram.*

The reflection of the cross falling upon the fovea centralis, that of the dot upon the optic pore.

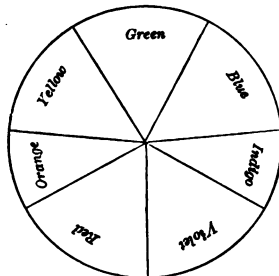
(1) The optic pore, which is *blind*, contains plenty of nerves, but not any rods or cones. Proof: make two dots upon a piece of paper, about three inches apart, close the left eye, and fix the right *continuously* upon the left point; at a distance of 15 in., the right point will be also visible; approach the paper to the eye, at a distance of about 10 or 12 inches, the right point will disappear for a short time, again appearing as the paper is approached nearer: the disappearance is due to the retinal image falling upon the optic pore or blind spot. (Each ear similarly seems to possess three deaf spots). (2) The sight is keenest at the macula lutea, where the nerves (as such) are absent. (3) The blood-vessels of the retina, which are among and outside the nerve-fibres, can sometimes be seen.

212. The sight is most acute where the *cones* are most abundant. The cones become more numerous relatively as they approach the centre, and in the centre itself, the fovea centralis, where the vision is most distinct, the bacillary layer consists of cones only. The cones are also relatively more abundant near the ora serrata. With keen sight, the size of the retinal images of the most minute (not-glittering) objects, which are *distinctly* visible, is about $\frac{1}{8000}$ in. diam., ($=\frac{1}{81,000,000}$ sq. in.!),—or even less. The retinal image is thus far less than the diameter of the cones, though many

think that each cone can convey but *one* impression, *movement* of the eye rendering vision more acute practically; which *may* be true.

213. Whether all colours are appreciated equally well by all parts of the retina is an open question. Some think that rays falling upon the exact centre are tinged with yellow (because of the yellow spot),—that red is best seen near the centre, then green, finally violet, whilst round the circumference no colour is seen at all, but only lights and shades: this does not appear to be so in *man*. White light is produced by the combination of all the colours—in black all colours are absent: the opposite holds with pigments,—light being represented in pigments by white; thus in pigments, black and white are practically colours, conventionally used separately, or mixed (forming greys), to represent amounts of light. All colours may be produced by combinations of three primary colours: these are with pigments, red, yellow, and blue; with lights, if they exist at all, probably red, green, and violet. The complementary of a colour is produced by the union of all the other colours. The complementary of a primary may be produced by the union of the other two primaries, but unequal quantities must be used. The ratio of vibration-numbers of complementaries is about as 4 : 5. If the colours of the solar spectrum were arranged in a circle, the spaces

FIG. 352.

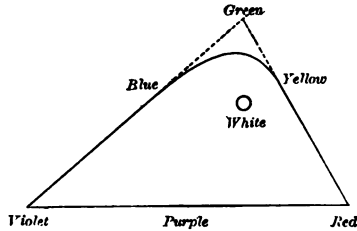


Newton's revolving disc for producing white light.

occupied by them would be about as follows: R. $60^{\circ}45'5''$, O. $34^{\circ}10'5''$, Y. $54^{\circ}41'$, G. $60^{\circ}45'5''$, B. $54^{\circ}41'$, I. $34^{\circ}10'5''$, V. $60^{\circ}45'5''$. It is to be remarked that purple is not represented in the solar spectrum. Helmholtz thinks that colours

arrange themselves as a scalene triangle, with red, green,

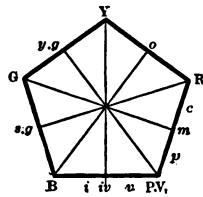
FIG. 353.

*Helmholtz's triangle of colours.*

The continuous line at green is the natural one. A line drawn from any colour through white will give the complementary (according to that author and others).

and violet at the angles, and white sub-central; but, judging by my own experiments, I believe that colours (pigments) may

FIG. 354.

*The Author's pentagon.*

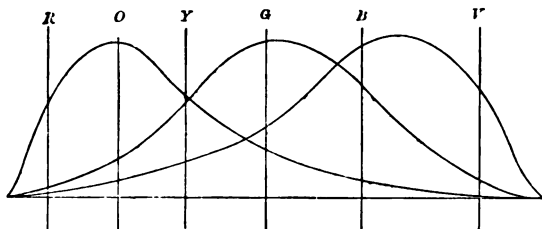
R red.
o orange.
Y yellow.
y.g. yellowish-green.
G green.
s.g. sea-green.
B blue.
i indigo.
iv indigo-violet.
v violet.
P.V. purplish-violet.
p purple.
m magenta.
c crimson.
(White in the centre.)

be arranged *practically* as a regular pentagon with red, yellow, green, blue, and (purple-) violet at the corners, and white in the centre; a line drawn from any colour through white will bisect the opposite side or angle at the complementary of that colour. The excitability of the retina is soon exhausted by looking at a bright colour, the retina becoming gradually insensible to that colour; and so, upon looking away from it, a spot of the complementary colour will be seen,—also while looking at it, a faint halo of the complementary is visible. If the object be white, the retina will become insensible to light, and the spot, &c., seen will be greyish,—the brighter the light the blacker the spot; thus upon going into a dark room, everything *at first* appears nearly black. A coloured iris will sometimes be seen surrounding the coloured spot, or ‘after-image,’ caused by

looking at a very bright object, e. g. the sun,—and the colours gradually change.

214. It would seem that both rods and cones are sensitive to light, the latter the more so, but that probably the cones alone appreciate colour; (the cones are absent, or very scanty in most nocturnal creatures). It is possible that the cones are of three classes, some appreciating orange more

FIG. 355.



Sensitivity of the three kinds of retinal fibres to the various colours. The height of the curves corresponds to the amount of sensation produced.

acutely, some green, and the others indigo; (and this might be effected [in man] by the different refractive power of the cone laminæ). This would account satisfactorily for the appearance of complementaries, owing to comparative exhaustion of one of the sets.

The outer segments of the rods are, in man, as in most vertebrates, stained during life with a rosy, purplish pigment—the visual purple, derived from the ‘choroidal epithelium,’ or purpurogenous membrane. The cones, yellow- and central- spots are all free from it. Owls have much; bats, doves, &c., none: it varies inversely as the coloured globules, where both are present. The rods bleach under bright light; but the frog, which possesses a few green rods also, seems to see about equally well without it. Its function is unknown; perhaps it is light-intensifying for the rods.

215. The eye, as an optical instrument, is admirably constructed, being very fairly achromatic, and capable of being adjusted for different distances; but still it is not perfect: though many instances of illusion are due to faulty judgment. Thus, through Astigmatism, we normally see horizontal lines as being nearer than vertical ones. Red requires more focussing than the other colours, i. e. is seen nearer. Again,

FIG. 356.

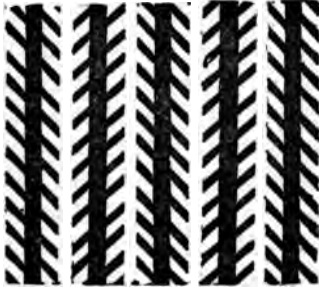


Diagram illustrative of optical illusions.

FIG. 357.



A, B, and C are really equidistant.

FIG. 358.

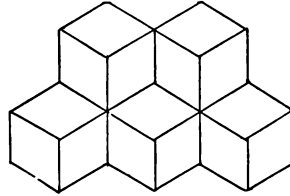
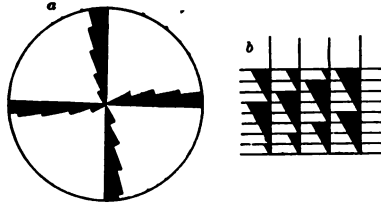


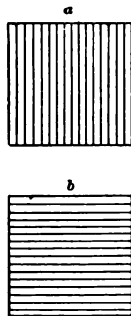
Diagram illustrative of optical illusions.
The lozenges sometimes appear as cubes in perspective.

FIG. 359.



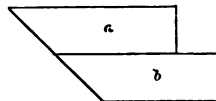
The disc *a* if rotated will appear as if a revolving spiral overlay it, the turns folding or unfolding according to whether the disc is revolved to the right or left. *b* shows the arrangement of the teeth upon the consecutive spokes. If the teeth were alike on all, the disc would appear shaded with four rings.

FIG. 360.



a looks broader than *b* or even than a square. *b* looks higher than *a* or a square.

FIG. 361.



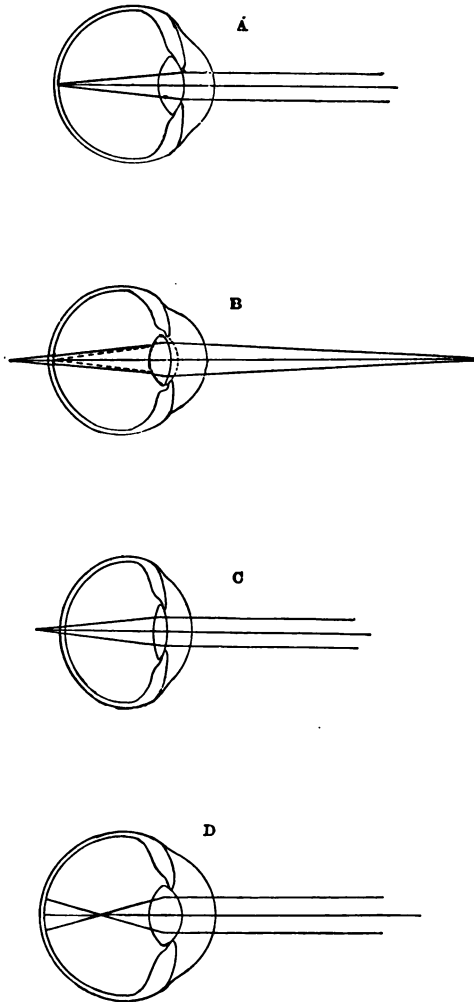
b appears the larger though both are equal.

lines, which appear vertical to one eye only, are about $1\frac{1}{4}^\circ$ out of the perpendicular: if two lines crossing each other at right angles (the one being horizontal) be regarded with the

right eye, the upper right and lower left angles will look larger (by $2\frac{1}{2}^{\circ}$ each) than the other two,—the other two angles appearing larger (by $2\frac{1}{2}^{\circ}$ each) to the left eye. If long thick parallel vertical lines be crossed by short thick parallel oblique ones, alternating in direction with alternate vertical lines, the vertical lines will appear to be alternately wider at top and bottom, towards whichever end the shorter ones point: the short ones will appear to be broken, and the upper half of one seem to belong to the lower half of the one above it: the effect of relief will sometimes also be produced, the paper appearing to be folded into longitudinal ridges. By a modification of the last example, parallel lines may be made to appear biconvex, or biconcave. Let A, B, and C be three equidistant dots in a line, between A and B make several more dots, A and B will then appear to be farther apart than B and C. A revolving screw appears to travel in the direction of its axis. A group of diamond lozenges will sometimes appear as cubes seen in perspective, three to each cube. A square, crossed by horizontal lines, appears higher than it really is; if crossed by longitudinal lines, broader. If two things of unequal magnitude be placed together, the larger object appears larger than it really is, and the smaller one, smaller: the moon appears larger near the horizon than in the zenith. When looking through a microscope and at other times, rows of minute watery globules and watery lines are seen on the field of vision, and sometimes single spots, which may appear fiery. The majority of these move more or less rapidly; hence their name—*muscæ volitantes*: their causes are various. The axis of (most acute) vision cuts the retina at the fovea centralis; it forms an angle of 5° ($3\frac{1}{2}$ —7)—the visual angle, with the optical axis (which is judged by the general conformation of the eye): the centre of rotation of the eyeball is slightly behind the centre of the visual axis.

216. The more distant an object, the sooner its rays come to a focus in the eye, so that when an object at a certain distance is distinctly seen, all others, whether farther or nearer, seem indistinct: e. g., having closed one eye, hold up a finger at a short distance in front of the face, and fix the gaze upon it;

FIG. 362.

*Diagrams of focussing.*

A emmetropic eye. (Normal sight.) Distant rays focussed on retina.

B emmetropic eye. Near rays coming to a focus behind the retina. The dotted lines show how accommodation is effected.

C hypermetropic eye. (Long-sighted.)

D myopic eye. (Short-sighted.)

then put another finger in front of the other, and several inches nearer the eye, the latter finger will appear indistinct

FIG. 363.

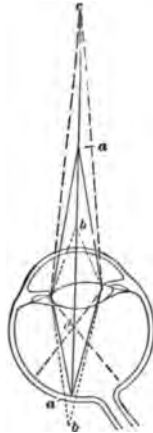


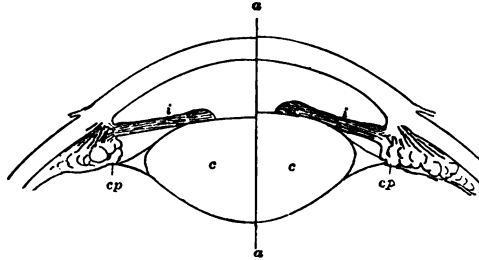
Diagram showing where rays come to a focus.

Rays coming from *a* meet at the retina at *a'* and are clearly seen. Rays from *b* meet behind the retina at *b'*. Rays from *c* meet before the retina at *c'*. Rays from both *b* and *c* are indistinct. This diagram is supposing the eye to have no accommodative power, and to be focussed for *a*.

until an effort be made,—which effort will be distinctly felt. The point of near vision (the nearest point at which objects can be distinctly seen) is about 4 or 5 in. : it increases with age from 2½ in. or less, to 12 ft. The point of far vision is infinite. When the eye is *at rest*, it is suited for looking at the most distant objects, i. e. the point of far vision : in order to see near ones, it requires a *voluntary* muscular effort to bring forward the focal point, which would otherwise fall behind the retina. It seems now to be pretty definitely settled that the cause of the adaptation of the eye for near vision is the alteration of the shape of the crystalline lens, especially of its anterior surface, produced by the contraction of the ciliary muscle ; but whether this, though certainly the chief, is the *only* cause, is still a matter of doubt ; (lengthening the antero-posterior axis *could* produce such an effect). In adapting the eye for near vision, the following internal changes are observable : the anterior surface of the lens becomes more convex, and is brought forward ; the posterior surface also becomes more convex, but its central part does *not* move forward appreciably ; the central part of the iris, round the pupil, is brought forward, but the peripheral

part is retracted ; the pupil generally becomes smaller, and the ciliary processes retire. The alteration of the shape of the lens is probably due to the contraction of the ciliary

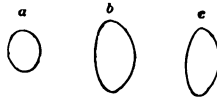
FIG. 364.

*Diagram of the accommodation of the eye.*

a, *a* optical axis. *c*, *c* crystalline lens. *i* iris. *cp* ciliary processes. The right part of the figure is focussed for near vision, the left side for far vision.

muscle, which loosens the suspensory ligament, and allows the elastic lens to assume a rounder shape. In looking at distant objects no movements are observed. The ciliary muscle, as before mentioned, alters with hypermetropia (usually called presbyopia), and with myopia. The antero-

FIG. 365.

*Crystalline lens.*

Side views (anterior surface to the left), showing alterations with age. *a* at birth. *b* adult. *c* in old age.

posterior diameter of the eyeball, as also that of the crystalline lens, diminishes with age ; the cornea also flattens.

217. Sensations of sight are (1) Purely optical: light, colour. (2) Involving muscular movements: apparent size, form, situation, visible movement, distance, and volume of objects. Why we perceive objects as being 'right-side up,' although their retinal images are inverted, is not known. It has been suggested that things appear to be above or below us from experience of turning our eyes up or down to look at them, but this does not seem to explain anything. Their vertical position is perceived in the brain, where the direction of the sensation is only relative: so that no special

arrangement is required, or else very possibly the optic nerve-fibres twist so that the lower fibres become uppermost, and so not inverted in relation to the centres of muscular movements of the eyeballs and the body generally. Pressure upon the eyeball gives rise to appearances of light, phosphenes (irises or peacocks'-eyes, and sparks).

218. The use of *two* eyes seems to be the appreciation of sensations involving muscular movements. The cause of single vision—why both eyes only convey one impression, seems to be that similar sensations produce but one impression, just as sounds produce but one impression, although there are two ears; but in order for the impressions to be similar, there must be a correspondence between the parts of both eyes. The upper and lower parts of both eyes respectively correspond, but the inner part of the left corresponds with the outer part of the right, and *vice versâ*, i. e. the right side of the one corresponds to the right side of the other, and so with the left sides. Among the reasons suggested are that the corresponding nerve-fibres (from corresponding parts) anastomose in the optic decussation, so that each pair forms one fibre, and thus transmit a single sensation to the brain,—and many others equally improbable. The impressions upon both eyes do *not* correspond *exactly* (the correspondence being perfect only in the exact centre, which is infinitely small, for a point has no magnitude but position only,—and more imperfect as we recede from the centre), and to this binocular dissimilarity is due our sense of perspective,—the volume or solidity of objects, and of their distances,—the eyes receiving slightly different impressions. N.B., the use of *Stereoscopic* photographs in restoring per-

FIG. 366.



Stereoscopic effect.

A as seen with both eyes. B as it appears to the right eye. C as to the left eye.

spective. To produce a single impression, the axes of vision must converge. The perception of perspective, as of most of the second class of sensations, is chiefly an intellectual

process, and not an intuitive one, and is capable of improvement by experience, for a child learns the distance of objects by experience—of touch. To show that perspective is chiefly due to the presence of two eyes, let a person *close one eye*, and attempt to pass a stick or a piece of string through a ring held edgewise to him at about arm's length, and he will notice the inaccuracy of his attempts: moreover, things will then appear flat, as in a picture; their shape and distance being judged of by colour-perspective, and by movements of the head. The nearer objects are, the clearer they appear,—the more distant, the more hazy their appearance (and colour), and the less marked by lights and shades, and a person also judges of their distance by this—light-perspective. By the two eyes, set a little apart, we see slightly round any small or roundish object, and more than a simple front view, each eye seeing a little more of the side of the object opposite to it: the brain combines the two impressions into one compound one. Each eye can rotate 34° upwards, 57° downwards, 45° inwards, 42° outwards; each can thus, more or less, command 110° vertically, and 130° horizontally (the two eyes rather more horizontally).

In looking at a near object, both axes of vision are made to converge so as to bear upon it, meeting in a point: both optical axes may not, however, be moved equally, for one eye may remain stationary: this accommodation, together with the ciliary one, takes about $\frac{1}{2}$ sec., usually from $\cdot 2$ — $1\cdot 18$ sec., to accommodate the eye to a nearer object than that at which it is gazing, $\cdot 15$ — $\cdot 84$ sec. for a more distant one; if beyond about 120 feet, the eyes do not move, and so the axes are parallel for the far point. The sense of muscular effort and consequent fatigue, if long continued, is probably due to the contraction of the internal recti muscles of the eyeball, and slightly, possibly, to the stretching of the external recti, and perhaps to the contraction of the ciliary muscle. The action of the ciliary muscle, though practically voluntary, is possibly due to a kind of reflex stimulus resulting from the voluntary convergence of the optical axes, and varying in proportion with it. We judge of the apparent size,—i. e. extent of vertical magnitude of objects,

by comparing them with other objects, and this partly by the muscular movements made in regarding (and comprehending) the whole of it, but partly by the amount of retina affected, though this possibly depends upon prior experience. Distance is calculated by the amount of convergence of the visual axis (and degree of contraction of the ciliary muscle?) by the apparent size, by light- and colour-perspective (both the effect of atmospheric moisture chiefly, N.B. fogs), and probably by the amount of binocular dissimilarity. The solidity of *distant* objects is rather a matter of mental conjecture than of actual vision, as in the case of nearer ones, for the binocular dissimilarity becomes less and less as the object becomes more distant.

CHAPTER VIII.

REPRODUCTION AND DEVELOPMENT.

219. THE reproductive, or generative organs, are situated in the pelvic region. The capacity for reproduction commences at puberty: (in England) in the male, generally at about the sixteenth year, gradually diminishing after the fifty-second; in the female, commencing about the fourteenth, and ceasing about thirty or thirty-two years afterwards. Hot countries, town life, &c., hasten its arrival.

220. In the male they consist essentially of two glands—

FIG. 368.

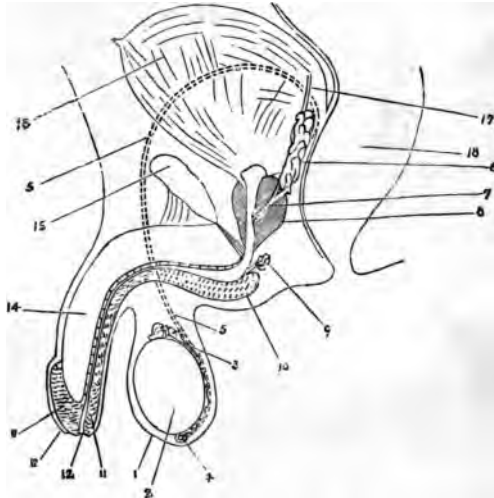


FIG. 367.



External generative organs of male.

p penis.
p' prepuce.
g unprotected part of glans.
u urethral orifice.
t, t' the testes in the scrotum.
r raphe of scrotum.

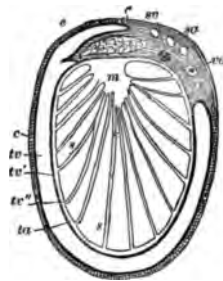
Semi-diagrammatical section of the male generative organs.

1 scrotum. 2 left testis. 3, 4 epididymis: 3 globus major, 4 globus minor. 5 vas deferens. 6 seminal vesicle. 7 ejaculatory duct. 8 prostate. 9 Cowper's gland. 10, 11 corpus spongiosum (dotted): 10 the bulb, 11 glans penis. 12 meatus urinarius. 13 prepuce. 14 corpus cavernosum. 15 symphysis pubis and ligaments. 16 urinary bladder. 17 ureter. 18 rectum.

the testes—which manufacture the semen, and an intermittent organ, the penis.

221. The testes are of an oval shape ($1\frac{1}{2}$ — $2 \times 1\frac{1}{2} \times \cdot 9$ in.; weight 1 oz): the left is usually rather the larger. Both are permanently lodged in a pouch or scrotum: the left hanging lower than the right. Each is invested by a serous sac, the tunica vaginalis, derived from the peritoneum, and also possesses a proper fibrous coat, tunica albuginea, which sends inwards a short septum, the mediastinum, from which thin processes radiate, dividing the parenchyma into about 300 lobules, each containing one or more long convoluted tubules, the tubuli seminiferi (in all 400 [250—840], $2\frac{1}{4}$ in. long), which end blindly or in a loop with a neighbour: they unite in front to form larger ducts—vasa recta—which unite to form a network, rete vasculosum, from which run several

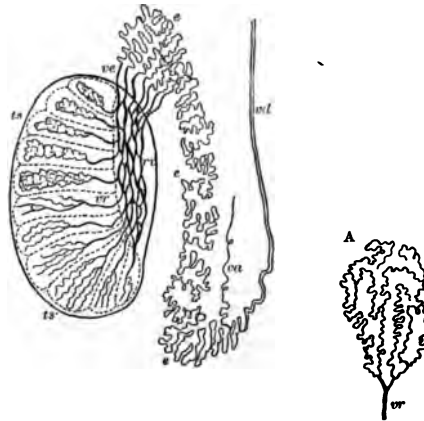
FIG. 369.



Supporting structure of testicle.

- c* connective-tissue.
- tc* cavity of, and
- tv tv'* outer and inner layers of tunica vaginalis.
- ta* tunica albuginea.
- m* mediastinum testis.
- s* septa.
- e* epididymis.
- vd* vas deferens.
- sv* spermatic vein.
- sa* branches of spermatic artery.

FIG. 370.

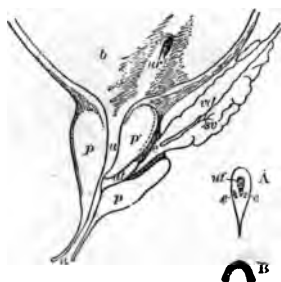


Glandular apparatus of testis.

- ts* tubuli seminiferi, at *ts'* uncoiled. *vr* vasa recta. *rv* rete vasculosum. *ve* vasa efferentia. *e* epididymis. *e'* its globus major, *e''* globus minor. *va* vas aberrans.
- vd* vas deferens. *A* diagrammatic course of tubuli seminiferi. *vr* a vas rectum.

ducts—*vasa efferentia*, into the epididymis—a minute convoluted duct about 20 ft. long, with a ciliated epithelium: continuous with it above is the *vas deferens*, which near its exit has a slight dilatation, and is there joined by a duct from the seminal vesicle,—both uniting to form the common ejaculatory duct, which opens just in front of the bladder into the prostatic portion of the urethra,—its mouth being visible on a little vascular projection, the *veru montanum*, or *caput gallinaginis*, composed partly of erectile tissue. In the centre of the *veru* is a small follicular depression or pit, the *sinus pocularis*, or *utricle*, at the edge of which, on either side, is seen the mouth of an ejaculatory duct, as mentioned. Belonging to the testicular apparatus are several unimportant little blind tubules, the *paradidymis* or organ of Giraldes; the *hydatids* of Morgagni (one or more); and the *vas aberrans*, a blind duct which empties into the epididymis. The walls of the *vas deferens* are capable of strong peristaltic contractions during ejaculation, &c. The seminal vesicles have numerous follicular depressions in their walls: they serve both as glands and as receptacles of semen. The urethra, from the *veru* downwards an uro-genital canal (7 in. long, 5—14 lines diam.), is divisible into three portions,—an upper prostatic, intermediate membranous, and lower spongy portion (the latter in the penis). The prostate is a

FIG. 371.



Antero-posterior median section of prostate gland, &c.

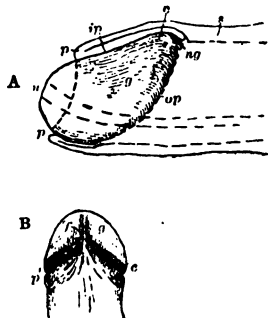
- b* bladder. *ur* orifice of ureter. *u* urethra.
p, p prostate. *p'* its 'middle lobe.'
ut utricle. *vd* vas deferens. *sv* seminal vesicle. *e* ejaculatory duct.
A veru montanum from before. *ut* mouth of urethra. *e, e* mouths of ejaculatory ducts.
B transverse section of urethra, opposite veru montanum, showing that body projecting into it.

partly muscular, partly glandular body ($1.4 \times 1.7 \times .75$ in. : weight 4.8 dr.), and consists of two lateral lobes. The parenchyma consists of compound follicular tubules, and possesses about twenty excretory ducts, which empty into the urethra. There are also in the urethra numerous mucous

follicles and lacunæ, and two small glands of the size of peas—Cowper's glands, which open each by a single duct into the membranous urethra.

222. The penis is for part of its length attached (along the perinæum, which is the space lying between the anus and the external generative organs); above is a very slight elevation, mons Veneris, covered with hair, which is also scattered over the scrotum. The free portion of the penis depends directly in front of the scrotum. The penis is chiefly composed of 'erectile' tissue, a *highly* vascular form of areolar tissue liable to great and sudden blood engorgement: this is found in three bodies, which run longitudinally, terminating posteriorly in bulby portions; these are the two corpora cavernosa, side by side, and below them the corpus spongiosum, which terminates anteriorly in an expansion, the glans penis, the chief centre of sensation, and free from the fibrous sheath, which elsewhere surrounds each of the three corpora, and from which dip processes into the interior; in the c^a cavernosa these are laminated, in the c. spongiosum reticulated. The glans is protected by

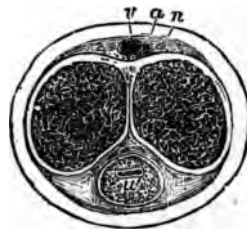
FIG. 372.



A lateral, and B under surface of the glans penis.

c corona glandis. f frænum. g glans. ip inner or mucous layer of prepuce. ng neck of glans. op the dotted line indicates the line of origin of the prepuce. p. p^e everted prepuce. s skin-covering of penis. u orifice of urethra. The urethra, and the edge of the prepuce are also indicated by dotted lines.

FIG. 373.



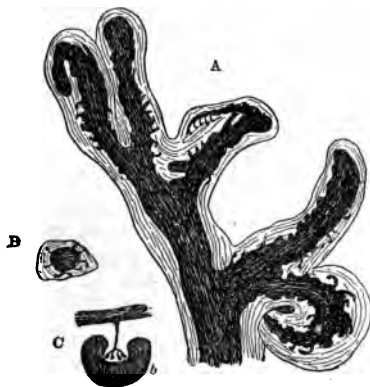
Cross-section of penis.

a, v, n dorsal arteries, vein, and nerve (above the two corpora cavernosa). u urethra (within the corpus spongiosum).

a fold of skin, the prepuce or foreskin, a continuation of the elastic and moveable skin which covers the penis, and

which possesses at its base modified sebaceous glands, those of Tyson; at the apex of the glans is the meatus urinarius; along and within the upper part of the c. spongiosum runs the urethra—here, as in the membranous and part of the prostatic portions, an uro-genital canal. The glans is a thick, somewhat cup-shaped, anther-like body, much longer above, enveloping the anterior termination of the cavernous bodies, the posterior edge—corona—running forwards below, as does the preputial attachment, here called the frænum: the inner (mucous) surface of the prepuce being attached to the 'neck,'—the base of the corona, and being continuous with the mucous surface of the glans, and lying in contact with it. During erection much blood is sent to the penis, and by the contraction of the voluntary muscles, and the engorgement of the helicine arteries—little branched arterial tufts which project into the veins, the veins become compressed in such a manner as to hinder the venous return until the excitation, and final orgasm accompanying ejacula-

FIG. 374.

*Helicine arteries.*

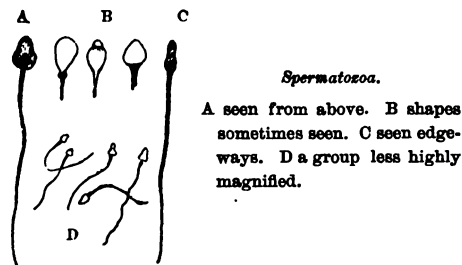
A longitudinal section (after Henle). B cross-section. C helicine tuft from artery projecting into vein *b*.

tion have subsided. The veins of the penis form a network. Some think that the ends of the helicine arteries are not quite blind, but are perforated by the mouth of a minute capillary which empties into the vein,—minute lateral capillary pits being found in their walls; these arteries are absent in

the glans. During orgasm the erectile tissue of the vern montanum causes this body to fill up the urethra, and prevent the backward flow of the semen into the bladder. (*Compressible* tissue is also found, e. g. in the walls of the urethra: this is liable to depletion, and consequent diminution.)

223. The semen, or spermatic fluid, as ejected (1—2 dr. each time) consists of the united secretions of the testes, of the accessory, or succenturiate glands—vasa deferentia, vesicles, prostate, and Cowper's glands, and also of the mucous glands. The essential element is the semen proper, secreted by the testes, and which consists chemically of 90 per cent. water, 6 per cent. of albuminoid matter—spermatine, neurine, protagon (containing phosphorus) and extractives, —and fats, 4 per cent. salts. It consists of a fluid medium for the conveyance of certain animalculæ-like bodies floating in it, and is derived from the granular cells of the tubuli seminiferi, which (in the adult) become peculiarly developed and freed; each is then called a sperm-cell, and contains from three to five (one to many) nuclei or spermatoa, each of which contains a single nucleolus, which develops into a *spermatozoon*, or zoosperm, which appears as a coiled spiral

FIG. 375.

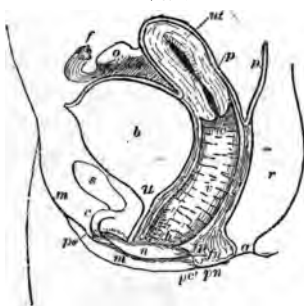


filament: in passing up the vasa deferentia the spermatozoa become freed, the walls of the spermatozoa first, and then those of the sperm-cells rupturing and dissolving; the spermatozoa then appear as little active bodies, which swim about in the spermatic fluid in a lashing, undulatory manner: they consist of a long ciliary tapering tail, and a minute flattish head which, viewed from above, is a rather ovoid pyriform,—sideways, is wedge-shaped. They are apparently structureless;

rarely a little dot is seen in the head: the fore-part of the tail is rather thicker than the rest, and is by some considered as a distinct part, the neck or body. Total length $\frac{1}{800}$, head $\frac{1}{8000} \times \frac{1}{8000} \times \frac{1}{28000}$ in. Several days are required for their complete development. Some describe the sperm-cells as little protoplasmatic columns projecting from the walls, and term them spermatoblasts. Many think that it is the nucleus which changes into the head of the spermatozoon, the tail either growing out from it, or developing from the surrounding protoplasm. The spermatozoa are the essential reproductive elements of the male. The secretions of the accessory glands probably serve as a medium of conveyance, and perhaps for protection of the spermatozoa (against acidity, &c.).

224. The essential female organs of reproduction are the uterus and two ovaries.

FIG. 376.



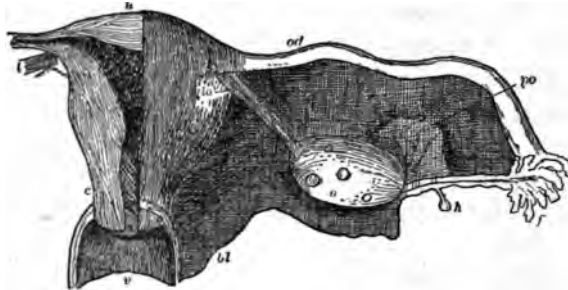
Generative organs of female. Antero-posterior section. Seen from left side. The viscera distended.

m mons Veneris. *pc* prepuce of clitoris. *c* clitoris (opposite the corpora cavernosa). *lm* labia majora. *n* nymphae. *b* bladder. *u* urethra. *o* ovary. *f* fimbriated extremity of Fallopian tube. *ut* uterus. *eo* external os uteri. *v* vagina. *h* hymen. *fp* fourchette. *fn* fossa navicularis. *pc* posterior commissure. *pn* perineum. *a* anus. *r* rectum. *p*, *p* layer of peritoneum overlying parts.

225. The uterus, womb, matrix, or *ὑστερον* is (in the fully-developed virgin, and pretty much so afterwards, excepting during pregnancy, when it is enormously increased) a pear-shaped body about 3 in. in length, weight 12 dr., and lies between the bladder and the rectum. Its cavity is a slender, solid triangle, and its walls consist of interlacing muscular fibres, which may be regarded as arranged in three complex layers, and are lined with a columnar epithelium, for the most part ciliated, supported by a nucleated basement membrane, with some cells and nuclei below it. The main body is termed the fundus, the two upper angles the cornua, into each of which runs a canal—the oviduct, or

Fallopian tube, which ends freely, close by the ovaries: the walls of the free or 'fimbriated' extremity of the tube are split up into fringes, and the canal here opens into the peritoneum, and so connects that serous sac indirectly with the air. The womb is connected with the exterior by means

FIG. 377.



Semi-diagrammatic view of uterus, ovaries, &c. (Seen from behind.).

v vagina. c cervix. u upper part of uterus (uterus and cervix partly bisected to show cavity). od oviduct or Fallopian tube. f its fimbriated extremity. h hydatid. po parovarium. o ovary. l round ligament. lo ligament of ovary. bl broad ligament.

of the os internum uteri, which opens into the cervix uteri, a short narrow canal which opens below by the os externum uteri into a larger and longer canal, the vagina, the walls of which are ordinarily for the most part collapsed, meeting

FIG. 378.



Antero-posterior section of vagina and uterus (in ordinary collapsed state). Seen from right side.

u urethra. h hymen.

FIG. 379.



Cross-section of anterior wall of vagina. Showing the two folds which project inwards. The orifice is the urethra (seen in section). After Henle.

antero-posteriorly: both canals have rugose walls, and the latter, and part of the former, a squamous epithelium with conical and filiform papillæ. A longitudinal projecting fold ('column,' sometimes double) runs up the lower part of both

anterior and posterior walls of the vagina. In the uterus are numerous glands—simple, slightly convoluted tubes, with a ciliated epithelium. The cervix also possesses follicular

FIG. 380.



Anterior wall of vagina, showing rugæ.

ou os externum uteri. *mu* meatus urina-
rius, a double longitudinal fold is
seen.

glands, and some others, ovula Nobothi, somewhat resembling closed follicles. The vagina (and vestibule) possess numerous muciparous glands and follicles; on either side of its entrance

FIG. 381.



Vagina laid open. (Somewhat foreshortened, and the posterior wall mainly visible.)

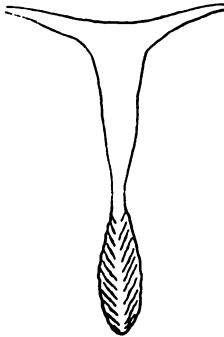
FIG. 382.



Rugæ of one side cervix uteri. ?.

is a largish gland ($\frac{1}{2}$ in. long), that of Bartholin or Duverney: its duct opens upon the inner surface of the nymphæ: its secretion, though ejaculated, plays no direct part in fertilisation. Around the vagina is erectile tissue, and non-striated

FIG. 383.



*The cavity of the uterus. Natural size.
(Virgin, æt. 17.)*

FIG. 384.



Uterine glands.

fibre, and around its entrance some striated also. The uterus and cervix also contain erectile tissue.

226. The external parts of the female generative organs are termed the vulva or pudendum. Above is an elevation, the mons Veneris, which, with the free part of the labia majora, is covered with hair: from the mons descend the two labia pudenda *vel* externa *v.* majora, at the edges of

FIG. 385.



The vulva from before. All the labia separated.

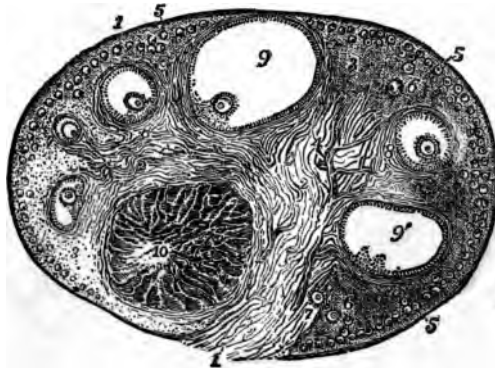
- pc* prepuce of clitoris.
- c* clitoris.
- r* rima.
- lm* labia majora.
- v* vestibule.
- n* nymphæ.
- u* meatus urinarius.
- v* mouth of vagina.
- h* hymen.
- p* perinæum.
- a* anus.

which the epidermis passes into mucous membrane: between them is a slit, the rima, in the front part of which is the clitoris; from the glands and prepuce of the clitoris run backwards the two nymphæ or labia interna *v.* minora, and

between these is the vestibule : into its floor opens the urethra ($1\frac{1}{2}$ in. long, 4 lines diam.) by the meatus urinarius, and behind this is the entrance of the vagina, which in virgins is generally partly occluded by an usually crescentic fold of membrane, the hymen : when this is ruptured, small rounded elevations, the carunculæ myrtiformes, remain. The crescent is concave forwards, and projects from the posterior wall of the vagina ; the orifice is sometimes more or less central. The clitoris is a rudimentary penis, and in the human being is not perforated. It consists of a glans with a rudimentary crescentic prepuce in front, and two corpora cavernosa : the c. spongiosum is represented by two rather large erectile-tissue masses of blood-vessels on either side of the vestibule ; these correspond to the bulby portion, the body being only represented by a small plexus (*pars intermedia*), which connects the glans and bulbs : all parts of the vestibule have a copious blood supply. The labiæ are united by an anterior and posterior commissure ; within the latter is a small fold, the fourchette or frænulum pudendi ; the commissures are not usually noticeable : the perinæum of the female is about an inch and a half in length.

227. The ovaries are flattish oval bodies ($1\frac{1}{2} \times \frac{3}{4} \times \frac{1}{2}$ in. ; weight $\frac{1}{6}$ oz.), invested by a coat originally derived from

FIG. 336.



Section of ovary. (Cat. Schrön ?.)

1 epithelium of free border. 1' attached border. 2 the fibro-vascular stroma. 3 fibro-nuclear substance. 4 blood-vessels. 5 earliest ovigerms. 6 passing inwards as they develop. 7 developing a Graafian follicle. 8 the same more advanced. 9 still further advanced. (9' the ovum accidentally escaped.) 10 corpus luteum, showing radiating cellular columns.

the peritoneum, and having a prismatic columnar epithelium, the germ-epithelium. Each consists of a stroma of vascular fibrous tissue (with a very little smooth muscular fibre), in which might be seen an enormous number, 70,000 (700,000?) of ova (in both ovaries), in various stages of development: beneath the epithelium the stroma forms a dense layer. The ovaries should be considered as undeveloped glands, which

FIG. 387.

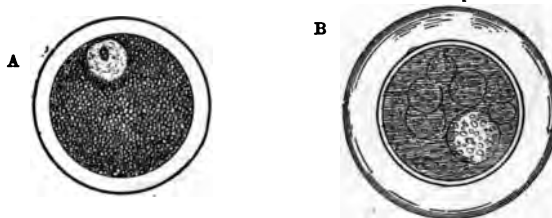


Section of ovary. Showing several Graafian follicles, and a corpus luteum.
(After Henle §.)

produce the ova. Lying upon the ovary are seen several blind transverse tubules, more or less of which are united by a longitudinal one: these constitute the parovarium, epoöphoron, or organ of Rosenmüller, near which are rarely found some minute scattered tubules, the paroöphoron. The ovaries are found one on either side of the uterus.

228. The ovum is the essential reproductive element of the female. Each consists of (1) a cell-wall, the vitelline

FIG. 388.



Ovum.

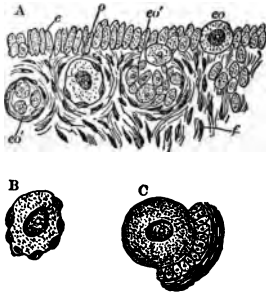
A shows vitelline membrane, yolk-contents, germinal vesicle, and dot. B shows more distinctly the character of the yolk.

membrane, or zona pellucida; (2) granular cell-contents, the vitellus, or yolk; (3) a nucleus, the germinal vesicle;

(4) a granular nucleolus, germinal dot. Size of smaller ova $\frac{1}{125}$ in. diam.; of larger $\frac{1}{100} - \frac{1}{20}$ in.; of germinal vesicle $\frac{1}{20}$; germinal dot $\frac{1}{3000}$. At first they are seen near the circumference, then they move towards the interior, whence, as they cannot be secreted there (as in some fish), they return again to the surface.

229. The first ova, the primordial ova, begin to appear at an early period in foetal life (about the tenth week). They are developed as follows: some of the germinal epithelium cells become enlarged and enclosed by outgrowths of processes of the stroma: these epithelial cells multiply: at first they are enclosed in groups in tubes, then singly: they also become enlarged: the small spindle-shaped cells

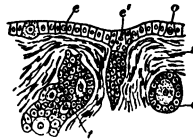
FIG. 389.



Development of primordial ova (fetus of 3 months).

- A portion of ovary. *e* germinal epithelium. *eo* an enlarged cell about to sink into the stroma and become an ovum. *eo'* two groups of enclosed ovi-germs. *o* a primordial ovum, surrounded by stroma. *f* fusiform corpuscles of stroma.
- B primordial ovum (like A *o*), showing the altered stroma corpuscles attached.
- C more advanced ovum; the fusiform corpuscles now a layer of granular cells, with surrounding condensed stroma about to form wall of Graafian follicle.

FIG. 390.



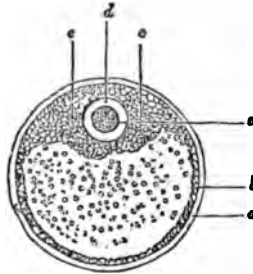
Development of primordial ova according to another theory, which makes the granular cells to be derived from multiplied epithelium.

- e* epithelium, multiplying at *e'* and forming a tube. *t* a tube more advanced. *o* large cells which become ova. *o* an ovum surrounded by the smaller cells. *s* stroma corpuscles.

of the connective-tissue around them multiply so as to form a layer of small cells: the large enclosed cell (rarely more than one) becomes the ovum,—the small cells the granular layer,—the group of both, the ovisac, Graafian-follicle or -vesicle: the connective-tissue forms a kind of layer of concentric fibres around each follicle. The granular layer *may* be derived from small embedded epithelial cells, and the

yolk-contents and membrane may be derived from protoplasm which gathers around the germinal cell which becomes the vesicle, and its nucleus the dot. The granular layer splits into two strata, an outer, the *membrana granulosa*, forming the vesicle wall, and an inner, the *discus proligerus*, surrounding the ovum: the latter is for some time much

FIG. 301.



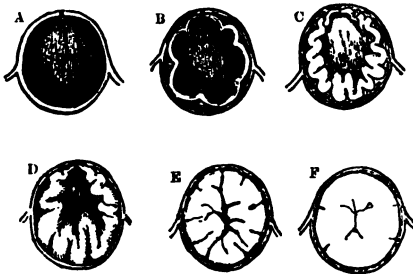
Section of Graafian follicle with ovum. (Beclard.)

a external coat. b membrana granulosa. c ovum. d vitelline membrane or zona pellucida. e, e discus proligerus.

thickened, especially at the part where it remains longest attached to the former, which also may consist of more than one layer: between both strata arises a clear fluid.

230. When the ova are fully developed, the vesicle bursts, and the ovum with its surrounding fluid is discharged externally into the peritoneal space, but is caught up by the

FIG. 302.



Corpora lutea. (After Ponchet.) In various stages of development, marked progressively A, B, C, D, E, F. The dark cavity is filled with a blood-clot, the white convolutions are the thickened epithelium.

FIG. 303.

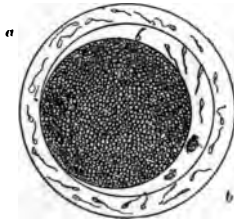


Wall of a corpus luteum.
(After Henle.)

application of the fringes of the fimbriated extremity of the oviducts to the ovaries, closing upon the ova so as to form a

canal. The vesicle bursts at the stigma—the part towards which all the minute blood-vessels converge, and the cavity is at first filled with a blood clot. The burst vesicle remains visible for some time as a corpus luteum: its endothelium proliferates gradually, filling up the cavity with bright yellowish cells. If impregnation have occurred, fat granules are found in the cavity, and the corpus increases very much during the first three months of pregnancy, rapidly shrinking after parturition, otherwise after twelve days or so,—traces remaining for some time longer. If unimpregnated, the corpus reaches a diameter of $\frac{3}{4} \times \frac{1}{2}$ in., impregnated, $1 \times \frac{3}{4}$ in. The ova are discharged periodically, a few at each menstruation, rarely at other times—sometimes *possibly* as the result of coitus; their discharge is termed ovulation. *Menstruation* corresponds to the rutting, or heat period of animals: it occurs monthly (each twenty-eight days) during the procreative period, and is marked by vascular excitement of the uterus, and, during about four days, by the extravasation of about 5 oz. of blood, &c., from it: the glandular structure is thrown off and renewed each time. As the ova pass down the oviducts, the discus proligerus is dissolved, and the ovum becomes fertilized by the spermatozoa boring through the vitelline membrane into the yolk. The vitelline membrane is, perhaps, porous, and sometimes displays a radiated columnar structure, but no distinct aperture—micropyle—is present.

FIG. 391.

*Impregnated ovum.*

The yolk is shrinking from the zona: in the interspace are seen two polar globules; numerous spermatozoa are also seen.

Usually many spermatozoa are observed about to enter (though one is probably sufficient). Conception takes place as the result of coitus: the os uteri descends slightly into the vagina as an occasional result of orgasm, and by a peculiar spasmodic action draws the spermatozoa in the semen

(forcibly) ejected against the os, as it were by suction, into the uterus (but this movement is not necessary); thence they pass upwards into the Fallopian tubes by their ciliary movements, aided possibly (but probably retarded) by the ciliary epithelial currents of the walls: finally they meet with the ova, and fertilize them. Fertilization generally takes place in the lower part of the oviducts. Usually *one* ovum only (in the human being) is fertilized,—why is unknown.

231. Nothing is known *for certain* as to the exact nature of what takes place in the ovum from the time of its impregnation till the appearance of the germinal membrane, and even afterwards. Upon the entrance of the spermatozoa the germinal vesicle and dot immediately disappear, as also do the spermatozoa themselves. The yolk then undergoes *segmentation*, at first splitting into two, each half subdividing again and again till a mulberry-like mass is formed, finally the cellular-bodies become very minute, and some of them acquire cell-walls, nuclei and nucleoli: as these become perfected, they rise to the surface, and line the vitelline membrane, with another membrane, the germinal membrane, or blastoderm, which is at first limited to a space upon one side of the yolk, but gradually spreads and surrounds it. Sometimes, though rarely, the germinal vesicle disappears, and the yoke segments, before fecundation. As the vitellus commences to segment, it shrinks, and a depression arises almost simultaneously upon either side, both gradually

FIG. 395.

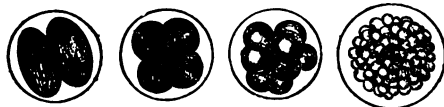


Diagram illustrating successive stages of yolk-cleavage in mammalian ova. (After Bischoff.)

deepening so as to divide the yolk: at the point where the depression commences there are seen outside the yolk a few globules (or one composed of several fused ones); these are termed the polar globules, and seem to be of no physiological importance, arising simply from the shrinking yolk, and again disappearing as the yolk swells out again. Some authors *think that the germinal vesicle and dot segment, each part*

drawing around it so much yolk for cell-contents, and so on till the cells are formed ; but it is more probable that the account above given is true. I believe that cell-nuclei, after their formation, may sometimes become dissolved into separate (usually coarse) granules, and that under certain circumstances these may again collect together to form a nucleus (or nuclei), as is very probably the case with chyle cells, and with the germinal vesicle, &c. Both germinal vesicle and dot separate into indistinguishable granules, as do the spermatozoa, and I think it probable that the spermatozoa granules unite with those of either the dot, or both dot and vesicle, and these new granules collect to form a nucleus and nucleolus, which would thus be the descendants of the germinal vesicle and dot respectively, plus the spermatozoa: this new cell then splits, each cell drawing around it the yolk as cell-contents, and so on till the blastoderm cells are formed,—which cells would be derived as follows: the cell-contents from the yolk, the nucleus and nucleolus from the germinal vesicle and dot respectively, together with the spermatozoa. The yolk substance primarily shows a tendency to form cellular masses.

232. The blastoderm at first consists of a single cornea layer, it then becomes double—a new layer of cells being formed within, making an outer corneal, and an inner endothelial layer: other cells as they form in the vitellus rise up and pass in between these two layers; this intermediate layer—the mesoblast, after a time splits into two; its outer layer adhering to the corneal layer, and for a time being also attached at its centre to its inner layer; thus, there are finally four layers which (passing from without inwards) are:

Somatopleure	{ (1) Epidermic or corneal	Epiblast.
	{ (2) Parietal	} Mesoblast.
Splanchnopleure	{ (3) Visceral or serous . .	
	{ (4) Endothelial	Hypoblast.

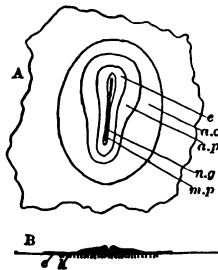
(1) is the serous and (4) the mucous layer of many authors: the mesoblast being termed the vascular layer. Older authors spoke of 1 and 2 as the serous, and 3 and 4 as the mucous layer, leaving the vascular portion rather ill-defined.

All these layers do not for some time (if ever) completely surround the yolk, but only occupy a part of the surface, termed the germinal area: finally, they *probably* do surround it. The mesoblast is at first very limited, and is thickened in the centre. All increase by supplies from below, and by cell multiplication 'inter se.' The hypoblast in some vertebrates is always limited, and probably the parietal layer also. The epiblast and parietal layers form the somatopleure,—the visceral and hypoblastic layers, the splanchnopleure: these two sets are separated (except in the centre) by the pleuro-peritoneal cavity.

What these layers ultimately develop into seems to be as follows: (1) the *epiblast* forms the epidermis and its appendages; the great nerve-centres; parts of the ear, eye, and nose. (4) the *hypoblast* forms the epithelium of the intestine, and of all glands connected with it, and also of the lungs. (2 and 3) the mesoblast forms the rest of the body; (2) its outer layer forms the organs of animal life—muscles, bones, &c.; (3) its inner layer those of organic or vegetable life—the viscera and vascular system.

233. The temporary adhesion of the mesoblastic layers in the centre gives rise to the appearance of the *nota primitiva*,

FIG. 396.



The embryo.

- A seen from above. *a.o* area opaca. *a.p* area pellucida. *e* embryo. *m.p* medullary plates. *n.g* neural groove.
B transverse section. *e* epiblast, coextensive with the *a.o* and embryo. *h* hypoblast, coextensive with *a.p* and embryo.

FIG. 397.



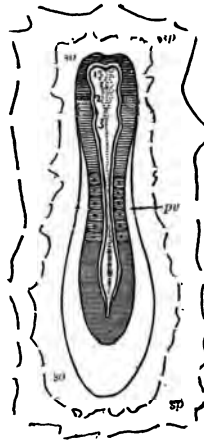
Area pellucida and embryo.

- m.g* the medullary groove forming in front of *p.g* the primitive groove.

a whitish longitudinal streak, which soon disappears: above it, there forms a furrow—the primitive groove, which either

becomes the neural groove, or *more probably* disappears : the neural groove appearing as a wide groove just in front of it (forming prior to the disappearance of the primitive groove). The germinal area now appears as a clear spot with an opaque border; the clear part—the area pellucida is thickened in the centre, the thickened part being termed the *embryo*; the opaque border is the area vasculosa. The hypoblast is coextensive with the area pellucida. The embryo appears as a slight elevation,—greater in the centre, down which

FIG. 399.



Embryo with part of blastoderm. (Dog.)

1, 2, 3 primary cerebral vesicles. *pv* the rudimentary protovertebrae are seen on either side of the neural groove. *so* upper layers of blastoderm. *sp* lower layers.

runs a longitudinal furrow, the neural (or medullary) groove : immediately on either side of this groove, the projections are termed the dorsal cristæ, laminæ, or plates.

The embryo now bends downwards in front, forming the involucrem capitis : the ventral surface, as it were, contracts, and the somatopleure folds in so as gradually to surround and cover more and more of the embryo with a sac. In the dorsal laminæ on either side are seen little square plates, the primordial vertebrae,—at first but three or four pairs next the head. Beneath the groove is seen a streak, the chorda dorsalis, or notochord, a cellular structure with a tough fibrous coat; from which layer it is derived is not

known. The dorsal laminæ gradually close over the groove, converting it into a tube, the neural canal, in one of the following ways: (1) The corneal layer is absent in the groove, and when the two corneal layers of the cristæ meet, the parietal layer of the tube curves round so as to form a tube, containing a minute central canal, the corneal layer not entering into the tube. (2) The corneal layer forms

FIG. 399.



Development of blastoderm.

A blastoderm of two layers (of egg newly laid). *e* epiblast. *h* hypoblast. *c* thickened central part. *e', h', c'* cells from each.
B blastoderm of three layers (egg after eight hours incubation). *e* epiblast. *m* mesoblast. *h* hypoblast. *pp* primitive groove (cut across) beginning to be formed.

the tube, and afterwards the connective tissue beneath the pia-mater (?) and the axis forms upon the walls of the groove, closing as it closes, and thus leaving the central canal; or (3) most probably the neural canal becomes this minute central canal, afterwards the cerebro-spinal canal, around which are thick walls, the future cerebro-spinal axis derived from the corneal layer, which is here very thick, and consists of several layers: the deeper layers, which always differ

FIG. 400.



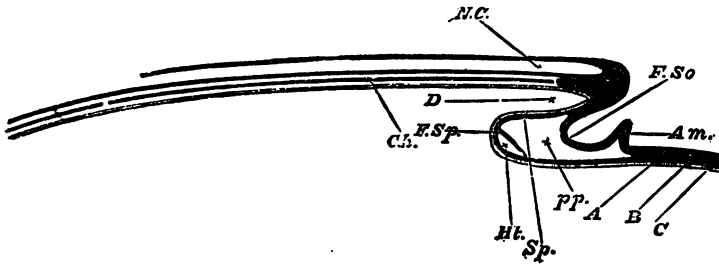
Transverse section of embryo of chick.

A at end of first day. B at end of second day.
e epiblast. *m* mesoblast. *h* hypoblast. *ng* neural groove which *mp* the medullary plates are gradually enclosing. *ch* chorda dorsalis. *pv* primordial vertebral plate commencing. *pv'* the same formed. *pp* pleuro-peritoneal cavity formed by the mesoblast there splitting into two layers. *mc* medullary canal, now closed in. *w* Wolffian duct. *a* aorta.

in some animals from the upper or true corneal one, form the nervous substance (possibly, but not probably, they are derived originally from the parietal layer): the corneal layer proper forms the endothelium—ependyma. At the anterior end of the groove—and afterwards of the canal, is a triple dilatation, the three primary vesicles. In the spinal

region, the central canal becomes double, the lower tube becoming the future central canal, the upper wall of the upper tube becoming gradually obliterated, and itself converted into the posterior fissure. The meninges are of mesoblastic derivation. The primordial vertebræ develop from before backwards, those of the coccyx appearing last,

FIG. 401.

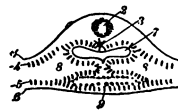


Diagrammatic longitudinal section of embryo. (Foster and Balfour.)

A epiblast. *B* mesoblast. *C* hypoblast. *D* commencing alimentary canal. *F.S.o* fold of the somatopleure. *F.Sp* fold of the splanchnopleure. *Sp.* pleuro-peritoneal cavity. *Ht* heart. *Am.* commencing (head) fold of the amnion. *N.C* neural canal (open behind). *Ch* notochord.

and as they develop they gradually constrict and absorb the notochord, which disappears entirely, and its sheath also. At the same time the neural arches, and the other skeletal parts begin to appear, all being at first in a rudimentary cartilaginous state: each vertebral segment has two cartilaginous centres, a right and left. Each primor-

FIG. 402.



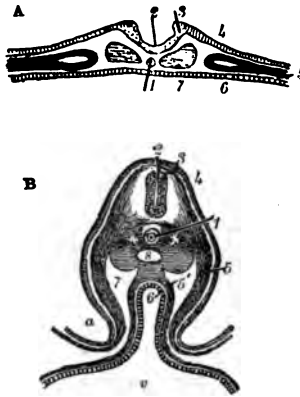
Section of an embryo.

1 epiblast. 2 neural canal. 3 notochord. 4 somatopleure. 5 splanchnopleure. 6 hypoblast. 7 digestive cavity with hypoblastic lining. 8, 8 pleuro-peritoneal cavities. 9 heart with endothelial lining.

dial vertebra, protovertebra, or more properly somatome, develops besides the bone, the muscles belonging, and also a nerve to each segment, so that the nerves, with the exception of their roots, belong to the median mesoblast, and seem to belong afterwards more particularly to the somatopleure, whilst the sympathetic nerves seem to arise

from the splanchnopleure. As the neural canal forms, the splanchnopleure also contracts so as to form a tube, the future alimentary canal. A thickening in the lower wall of the canal at the involucrum capitis gives origin to the heart, whilst the blood-vessels spread out peripherally so as to enclose more and more, but never the whole, of the yolk. The pleuro-peritoneal cavity afterwards becomes the cavities

FIG. 403.

*Transverse section of embryo. (Chicken.)*

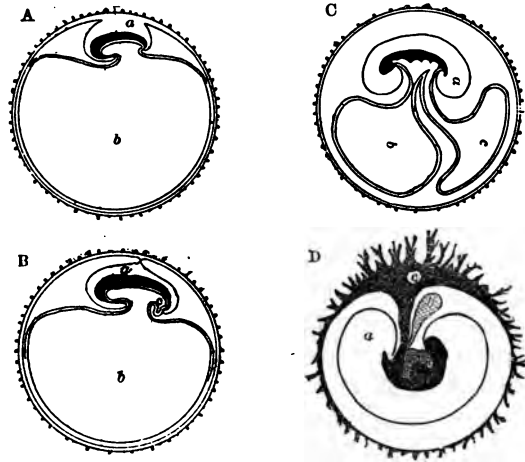
- A at end of first day. 1 notochord. 2 neural groove. 3 dorsal crest. 4 epiblast. 5 mesoblast (split near centre). 6 hypoblast. 7 protovertebral plate.
 B on the third day. 1 notochord. 2 medullary canal. 3 spinal cord. 4 epiblast. 5 somatopleure. 6 splanchnopleure. 7 pleuro-peritoneal cavity. 8 aorta. a amniotic cavity. v yolk-cavity.

of the pericardium, pleuræ, and peritoneum. Some think that a layer of visceral cells lines the somatopleure, so that the pleuro-peritoneal cavity would be within the visceral layer, the outer layer forming the outer layers of the serous membranes, pleuræ, &c., the inner, the reflected portions, and the intestines. The central united part of the mesoblast is the mesial or vertical plate, from which spring the vascular system and the various organs of vegetable life.

234. In the meanwhile the corneal and parietal layers have begun to rise up round the embryo, and this continues till the sides meet and form a sac or vesicle—the *amnion*, which nearly envelopes the embryo as with a serous sac, the outer wall of which becomes incorporated with the chorion. The

amniotic fluid—liquor amnii, is .99 water, with a little albumen, salts, &c.: it increases in quantity till the 5th month,

FIG. 404.



Ovum with embryo.

A, B, C, D represent successive stages in the development of *a* amnion, *b* yolk-sac, *c* allantois.

then remains stationary, and is discharged at birth, when it is about a quart.

235. The mucous membrane enclosing the yolk at the same time contracts, especially the portion next to the embryo, so that the yolk sac—now termed the umbilical vesicle—is only united to the embryo by a pedicle—the vitelline duct, which at first opens into the digestive canal, but afterwards closes. As the umbilical vesicle begins to wither away, a new sac pushes out from the anal end of the intestine—this is the *allantois*. So the intestine has in all four communications; (1) oral with the amnion; (2) vitelline with the yolk—near the termination of the ileum at a place marked externally by the navel; (3) with the allantois, which opens into the ventral surface of the cloaca; (4) cloacal with the amnion: all these orifices close sooner or later. The allantois gradually surrounds the embryo, and its outer wall becomes incorporated with the chorion. A network of blood-vessels spreads out in the walls of the allantois, as in those of the umbilical vesicle; and besides this, the chorion

developes small papillary tufts—villi, which at first rapidly cover the allantois, but are afterwards limited. The allantois also becomes constricted at its junction with the embryo: the intra-embryonic portion becomes converted into the urinary bladder; the constricted portion (which closes) is the urachus. The allantoidal fluid seems to be urinary in function, and secreted by the two primordial kidneys, or Wolffian bodies, which are proportionately large, and occupy the whole length of the abdomen.

236. The yolk-sac is for a time surrounded by all the layers; but, as it shrinks, by the splanchnopleure only. The amnion is formed by two layers, inner epiblastic, and outer parietal. The allantois is also formed by two layers, outer visceral, and inner hypoblastic. As the new layers of cells push out against the chorion, the outer ones probably become absorbed, so that ultimately the allantois becomes a substitute for the chorion.

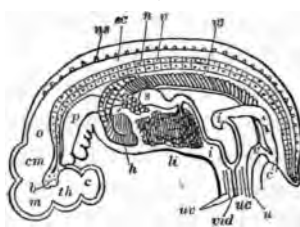
237. As the embryo begins to assume a form in which may be traced resemblances to the adult, it becomes termed the

FIG. 405.



Fœtus of nine weeks. Showing the umbilical cord and part of chorion. *v* yolk-sac. *i* intestine.

FIG. 406.



Longitudinal section of fœtus of six weeks.

- c* cerebrum. *th* thalamencephalon.
- m* mesencephalon. *cm* cerebellum.
- o* medulla oblongata. *ns* neural spines. *sc* spinal cord. *n* notochord.
- v* vertebral spines. *w* Wolffian body. *b* basi-cranial flexure.
- p* pharynx. *h* heart.
- l* lung. *s* stomach. *li* liver.
- i*, *i'* larger intestine. *i'* smaller intestine. *v* bladder.
- cl* cloaca.
- uc* umbilical cord, containing *vid* vitello-intestinal duct. *u* urachus.
- uv* umbilical vesicle, (2 arteries and 2 veins.)

fœtus (at about three weeks old). Regarding the development of the various parts, the following must suffice.

238. The primary, or vitelline circulation, which overruns

the greater portion of the umbilical vesicle, is *single*, and is termed the omphalo-mesenteric system. Its limit is ring-like—the vena circularis, which spreads out as the system develops. The blood is conveyed to and from the heart by the omphalo-mesenteric arteries and veins, two of each. Each artery is at first continuous with the vein of its side, so that there must be two ‘hearts,’ each a simple tube: but shortly the two coalesce, so as to form *the* heart, which becomes dilated in such a way that three divisions may be noted, an auricle, a ventricle, and an arterial bulb. The heart arises as a hollowing-out in the visceral layer of the splanchnopleure of the lower intestinal wall, and soon acquires an endothelium.

239. Whilst the above system atrophies, as it does rapidly upon the closure of the connexion between the intestine

FIG. 407.

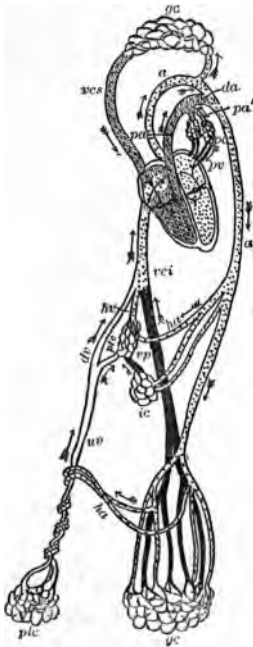


Diagram of fetal circulation. (The lymphatic system is ignored.)

The arrows indicate the direction of the currents. The shading indicates the degree of impurity of the blood.

gc, gc greater circulation.

pc lesser or pulmonary circulation.

plc placental circulation.

ic circulation of intestines, &c.

pte portal circulation.

vci, vcs vena cava inferior and superior.

pa pulmonary artery.

pa' its two branches.

da ductus arteriosus.

pv pulmonary veins.

a aorta.

ha hepatic artery.

ua the two umbilical arteries.

uv umbilical vein.

vp vena portæ.

hv hepatic vein.

dv ductus venosus.

and yolk-sac, the secondary or allantoidal circulation arises. The two arteries—now the primordial aortæ—soon become

fused below to form the abdominal aortæ; their curve is termed the aortic arch—the first of a series about to be developed; the part of each aorta upon the heart side of the arch may be termed the anterior aortic root, the other part

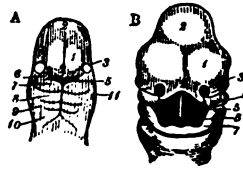
FIG. 408.



Diagram representing the branchial arches of mammals, with the changes induced therein. (After Rathke.)

a, a aorta. b common pulmonary artery. c, d right and left pulmonary arteries. e truncus arteriosus obliterated at birth. f innominate artery. g, g subclavian arteries. h vertebral arteries. i common carotid. k, k, l, l internal and external carotids.

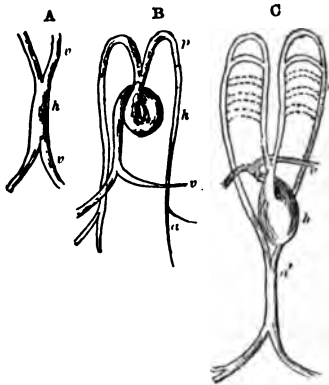
FIG. 409.



Heads of two embryos.

A of twenty-one and B of thirty-five days. 1 anterior cerebral vesicle. 2 middle vesicle. 3 eye. 4 nasal process. 5 mouth. 5' tongue. 6 superior maxillary process. 7 inferior maxillary process. 8, 9, 10 2nd, 3rd, and 4th branchial plates, and their clefts beneath each. 11 ear.

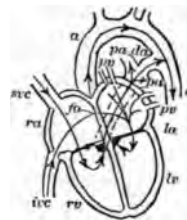
FIG. 410.



Diagrams of fetal heart and primitive arteries.

A, B, C successive stages. a arteries. v veins. h heart. p primitive aortic arches. p' their continuation. b branchial arches. a' united aorta.

FIG. 411.



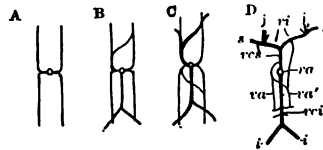
Fetal heart and great vessels.

(The arrows indicate the course of the blood-currents.) la, la left auricle and ventricle. ra, ra right auricle and ventricle. sce, sce superior and inferior vena cavae. pc, pc pulmonary arteries. pv, pv pulmonary veins. da ductus arteriosus. a, a aorta. fo foramen ovale.

the posterior aortic root. There arise five pairs of branchial arches, the posterior appearing as the anterior atrophise: they pour in front into the anterior aortic root, behind into

the posterior one. The 1st, 2nd and 3rd pairs of arches become the future carotids, the 4th left arch forms the *aorta*, the 4th right arch is represented simply by the right subclavian artery, the 5th left arch becomes the trunk of the pulmonary arteries, the 5th right one disappears. The common arterial trunk or bulb, *truncus arteriosus*, splits lengthwise into the roots of the aorta, and pulmonary artery trunk, which, however, are long connected by the *ductus arteriosus* (Botalli), the remnant of the outer part of the 5th left arch. The arteries are at first two in number; within the embryo they are termed hypogastric, without it um-

FIG. 412.

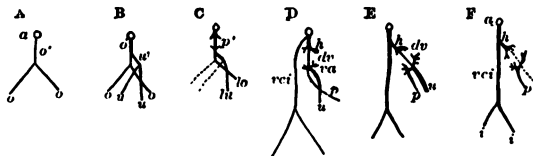


Development of venous system.

A primitive state. D adult state. *ra* right auricle. *vas* vena cava superior. *vi* the two vena innominatae. *j* jugular veins. *s* subclavian veins. *va, va'* greater and lesser azygos veins. *vei* vena cava inferior. *i, i* two iliac veins.

bilical. The omphalo-mesenteric veins unite to form a short common trunk, from which spring out small veins

FIG. 413.



Development of the portal circulation.

a right auricle. *o, o* omphalo-mesenteric veins. *o'* their common trunk, *meatus venosus*. *u, u* umbilical veins. *u'* common trunk which runs into the *m. venosus*. *lo, lo* left omphalo-mesenteric and umbilical veins, the right having disappeared. *p'* veins of the liver arising. In D *vei* vena cava inferior arising, runs into the common trunk. *lo* the left omphalo-mesenteric becoming the portal vein. *va* vena advehentes. *dv* ductus venosus. *h* hepatic veins. *dv* and *u* finally disappearing. *i, i* common iliac veins.

which develop into the portal system; the common trunk becomes the ductus venosus, the left omphalo-mesenteric vein the portal vein,—the right soon disappearing, as also the right umbilical vein; the left umbilical vein also finally atrophies, becoming the broad ligament of the liver: the inferior vena cava arises as a small vein, which pours into the

common trunk. The umbilical veins are at first two in number, and pour, by a short common trunk, into the common omphalo-mesenteric trunk; but the right one disappears, and the blood of the left pours partly into the portal vein, partly as the *ductus venosus* into the inferior vena cava. The arteries and vein are twisted spirally (the former the more so) in the umbilical cord, which enters at the navel, and which, besides these three, consists of the pedicles of the yolk-sac and allantois.

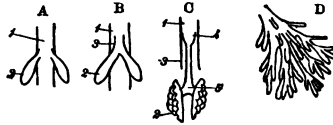
240. The heart is at first a single long chamber, or rather an enlarged tube. The ventricular septum is first formed: a slight external, interventricular groove appears for a time. The auricles are connected until birth by the foramen ovale, which has a valve that becomes fastened down, occluding the orifice. Though the heart is thus for some time a kind of three-chambered one, the blood is not much mixed in passing through it, for the blood coming from the inf. vena cava, passes in a current across through the foramen ovale, and down into the left ventricle, whilst that from the sup. vena cava passes down into the right ventricle, and these currents become less and less intermingled as the foetus develops. Since respiration does not take place in the foetus, arterialized blood is derived from the placenta, so that the quality of the blood in different parts varies, owing to the above-mentioned peculiarities: the blood going to the head passes off before the junction of the aorta and ductus arteriosus, so that it is tolerably pure, whilst that going to the body generally is very impure. The foetal blood is of nearly the same colour throughout the body.

241. The red blood-cells of the foetus are larger than in the adult: in the earlier stages they are nucleated, and at first are both colourless and nucleated: so that the red blood-cells (many of them, at any rate) are derived from shrunken white cells. The liver in the foetus gives rise to blood-cells. In the earliest foetal stages the blood-corpuscles arise in several ways; sometimes in a large cell or vesicle are seen many nuclei, these multiply, and protoplasm gathers around each; thus they develop into blood-corpuscles, whilst some of the outer ones form an endothelium to the

walls: at other times, the corpuscles seem to spring from detached portions of the vesicle walls.

242. The lungs develop as two little sacs, which push backwards from the œsophagus: they soon become pediculated; the stalk lengthens out and becomes the future trachea, while the bifurcations become the bronchi, and develop the two air-trees of the lungs, upon the plan of compound race-

FIG. 414.



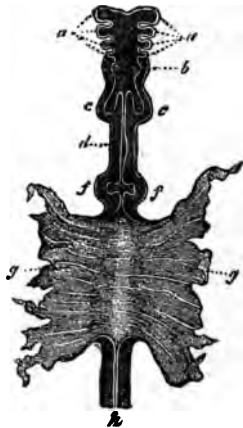
Posterior view of the œsophagus and lungs. Showing the development of the lungs, A, B, C, and of the bronchia D.

1 œsophagus. 2 lungs. 3 trachea. 4 larynx. 5 bronchi.

mose glands. The middle lobe of the right lung, if judged by the bronchial development, would belong to the lower lobe, but it is supplied with pulmonary blood by the upper branch of the pulmonary artery, and the upper pulmonary vein conveys it away; the lower fissure too corresponds with the left one.

243. The intestines at first form a straight tube, which

FIG. 415.

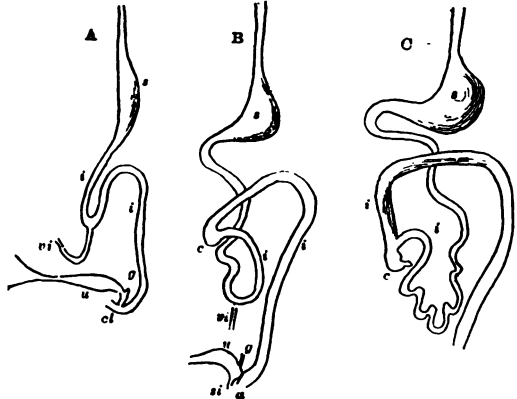


Development of alimentary canal. (Kölliker.)

a four pharyngeal plates. b pharynx. c, c lungs. d stomach. f, f liver. g yolk-sac (into which the intestine opens). h posterior part of intestine.

afterwards becomes convoluted, and its appurtenances (liver, &c.) develop. The liver soon becomes very large.

FIG. 416.



Development of alimentary canal. (After Quain.)

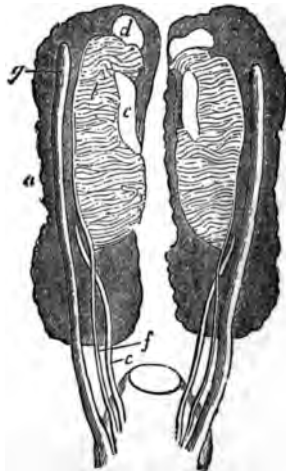
A at five weeks. B at eight. C at ten.

s stomach. i, i intestine. c cæcum. vi vitello-intestinal duct. cl cloaca. u urinary bladder. g genital ducts. si uro-genital sinus. a anus.

244. The mouth and nose are at first open together: their epithelium is for the most part of epiblastic origin. The imperfect closure of the upper lip causes 'hare-lip.'

245. The kidneys arise in contact with the Wolffian

FIG. 417.



Wolffian bodies, &c., of fetus.

(Bird. J. Müller.)

a kidney.

b tubular part of Wolffian body.

c ovary (or testis).

d supra-renal capsule.

e ureter.

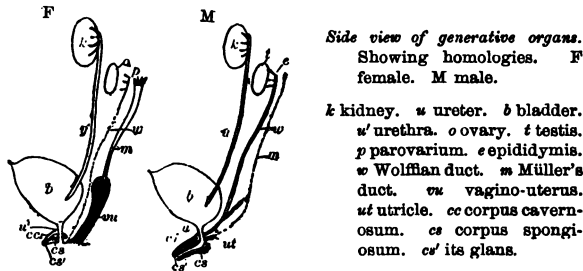
f Wolffian duct.

g Müller's duct.

(The ducts open into the cloaca.)

bodies: they are at first lobulated, the lobes corresponding to the pyramids. The generative organs (ovaries or testes, and appurtenances) arise in their immediate neighbourhood, and are derived from modifications of the Wolffian bodies and adjacent blastema, the pleuro-peritoneal or germ-epithelium entering into the formation of the ovaries, and some of the cells becoming ovigerms or primitive ova: enlarged cells are at first seen in the male, but the germinal epithelium soon seems to disappear. The Wolffian body and its successors all arise in the mesian plate from a small separate cord termed the intermediate cellular mass. This mass displays two modifications of its epithelium: these become (1) the germ-epithelium; (2) by involution, the Müllerian ducts. Each Wolffian body consists of numerous slightly

FIG. 418.



convoluted tubes, which are blind inwards, but at their outer ends open into the Wolffian duct, which empties into the cloaca: these ducts first develop. The permanent kidneys arise as diverticula from the Wolffian duct. The reproductive organs arise chiefly from the intercellular mass beneath the germ epithelium. The Müllerian ducts are open above, and at first are connected below with the Wolffian ducts, presently, some think, conjoining for some distance, and so forming, in the female, the uterus and vagina: whilst others look upon the vagina and uterus as a recess developed from the cloaca. The reproductive organs arise at the upper, and the kidneys at the lower part of the Wolffian bodies. For the first twelve weeks the sexes are not distinguishable, whilst for ten weeks there is even a

cloaca, or united fæcal and urino-genital chamber, with excretory aperture, and there is in front a peni-clitoris, grooved beneath: then the anal aperture separates from the urino-genital one, the septum being the future perinæum.

FIG. 419.

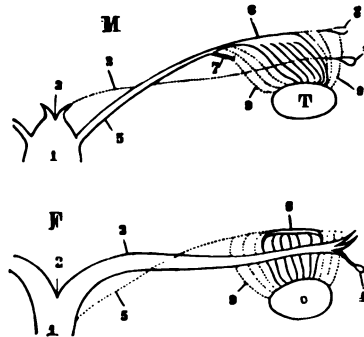
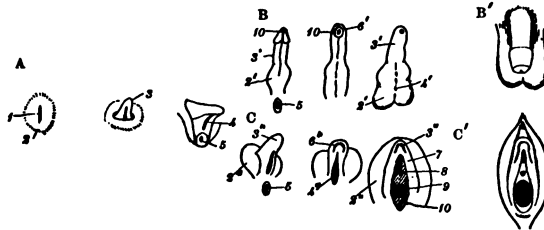


Diagram of the development of the internal generative organs. (Beauvais et Bouchard.)

- M** masculine type. T testicle. 1 uro-genital sinus. 2 orifices of Müller's two ducts, forming the prostatic utricle. 3 portion of Müller's duct which disappears. 4 other extremity forming the pediculated hydatid of Morgagni. 5 Wolff's duct. 6 the portion which becomes the canal of the epididymis. 7 vas aberrans. 8 non-pediculated hydatid of Morgagni. 9, 9 parts of Wolffian body which disappear. 6 and T are connected by the head of the epididymis.
- F** feminine type. O ovary. 1 uro-genital sinus. 2 uterus. 3 Müller's duct, which becomes the Fallopian tube. 4 hydatid of Morgagni. 5 Wolffian duct, which mostly disappears. 6 portion which becomes the parovary and its main duct. 9 parts of Wolffian body which disappear.

FIG. 420.



Development of the external generative organs.

- A common type. B masculine type. C feminine type. B' C' adult forms.
- 1 cloacal aperture. 2 elevation of skin. 3 genital tubercle. 4 uro-genital aperture. 5 anal orifice. 6 scrotum. 7 labia majora. 8 penis. 9 clitoris. 10 raphé or ridge of scrotum. 11 vestibule. 12 prepuce. 13 labia minora. 14 urethral orifice. 15 orifice of vagina. 16 hymen. 17 male urethral (uro-genital) orifice. In C' the Mons Veneris and external portion of labia majora are not shown, and all the labia are separated.

Afterwards, the organs in the female do not alter materially, the peni-clitoris becoming the clitoris, the groove remaining open as the vestibule, whilst in the male sex the peni-clitoris

becomes the penis, and its groove closes up, forming the spongy portion of the urethra : thus the clitoris (+ nymphæ) is the homologue of the penis, &c. Both testes and ovaries leave their original position, the former descending into the scrotal pouch, usually during the 9th foetal month (in about $\frac{2}{3}$ of the cases have descended at birth). The following homologues (here roughly given) are to be noticed :—

Male.	Embryo.	Female.
Testis.	Reproductive blas- toma.	Ovary.
Vas efferens, paradidymis.	Wolffian body.	Paroöphoron.
Epididymis, vas deferens, and seminal vesicle.	Wolffian duct.	Epoöphoron.
Prostatic vesicle and hy- datids of Morgagni.	Müllerian ducts.	Fallopian tubes (Uterus and vagina?).
Cowper's glands.	(Blastema).	Duverney's glands.
Penis.	Peni-clitoris.	Clitoris, plexuses & nymphæ.
Spongy urethra.	Groove.	Vestibule.
Scrotum, &c.	Skin.	Labia majora.

246. Regarding the nervous system, some think that nerve fibres are developed by nuclei travelling from the axis outwards : the nerve cords seem, however, like the axis, to

FIG. 421.



Transverse section of spinal cord of embryo of six weeks.

a the anterior, and *g* the posterior columns of white substance, which is at first cellular, beginning to be separated from *g* the grey substance. *ar* anterior, and *pr* posterior nerve roots. *c* central canal. *e* its epithelial lining. *c'* place where the canal originally closes, and which again opens, forming the posterior median fissure, closing behind at *c''*.

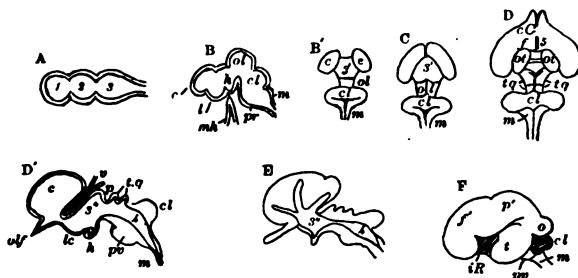
arise from cell-multiplication (as do the other parts of the body). The brain arises from the three primary vesicles, both the anterior and posterior of which may again be divided into two. They develop the following parts :—

1. Ant. { 1. Prosencephalon, cerebrum, c. callosum, c^a striata, fornix, &c. :
 olfactory bulbs (Rhinenkephalon).
2. Thalamencephalon, thalami optici, pineal and (part of)
 pituitary bodies, 3rd ventricle, optic nerve (primarily).
2. Mid. 3. Mesencephalon, c. quadrigemina, crura cerebri, aqueduct of
 Sylvius, optic nerve (secondarily).

3. Post: { 4. Epencephalon, cerebellum, pons Varolii, anterior part of 4th ventricle.
5. Metencephalon, medulla oblongata, 4th ventricle (mostly), (auditory nerve).

The cerebral hemispheres, which are at first smooth and hollow, spring from the first of the three vesicles; the roof of the intermediate portion (which appears afterwards) is

FIG. 422.

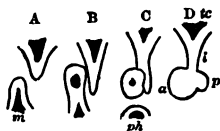


Development of the brain in fetus.

A, B, C, D, E, F successive stages. 1, 2, 3 primary, secondary, and tertiary brain-vesicles. *m* medulla oblongata. *po* pons Varolii. *ol* cerebellum. *ol* optic lobes, afterwards *tq* tubercula quadrigemina. *A* hypophysis cerebri. *c* cerebrum. *l* lamina cinerea. *ma* hypoblastic involution of mucous membrane. *3'* roof of 3rd ventricle *3''*, which develops the two optic thalami *ot*, connected by the median commissure. *5* fifth ventricle, beneath it the fornix *f*, above it *cC* the corpus callosum. *4* fourth ventricle. *p* pineal gland. *v* velum interpositum. *olf* olfactory lobe. *f'*, *p'*, *o*, *t* frontal, parietal, occipital, and temporal lobes of cerebrum. *IL* island of Reil.

formed by the *c*. callosum, the floor by the fornix and lyra; the fifth ventricle for a time communicates with the third; from the anterior end of each hemisphere springs a small lobe—the olfactory—which is at first hollow, its cavity being continuous with the lateral ventricle of its side. The ventricular cavities are tri-radiate, the posterior cornu appearing last. The anterior lobe of the pituitary gland or

FIG. 423.



Development of the hypophysis.

n nervous, and *m* mucous elements, which develop into *a* anterior, and *p* posterior lobes. *i* infundibulum. *t* tuber cinereum. *ph* pharyngeal cavity.

hypophysis cerebri, is derived from the epiblast, pushing up from the mouth, and then becoming shut off from it: the posterior lobe is simply a prolongation of the infundibulum. The *c''* quadrigemina are at first a single hollow protuberance,

then a longitudinal furrow arising—a hollow pair, rather more lateral in position than they afterwards are. The optic thalami arise as thickenings in the walls of the third ventricle; they soon become separated. The floor of the thalamencephalon is formed by the lamina cinerea.

247. The eye is developed partly from a vesicular outgrowth from the brain, partly from an integumentary involution, partly from the surrounding parts. The inner wall of the brain-process—the optic vesicle—becomes the retina proper, the outer wall the *pigmentary epithelium*.

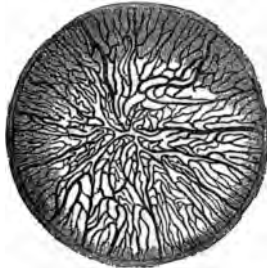
FIG. 424.

*Development of the eye.*

A first appearance. 1 epidermic involution. 2 primary optic vesicle—a protrusion of the brain. B the same further advanced. C shows the development of 1 the epidermic involution into the crystalline lens, 2 the anterior wall of the vesicle into the retina, 2' the posterior wall into the pigment epithelium, 3 the secondary optic vesicle.

The epidermic ingrowth when enclosed forms the lens,—the anterior layer becoming the anterior layer of cells, the posterior layer the fibre-cells. The other parts of the eye

FIG. 425.



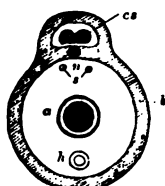
Pupillary membrane of fetus injected. Showing the blood-vessels. (New-born kitten. Kölliker.)

are derived from intruded cells. The pupil is at first closed by a very delicate membrane. The eyes are at first nearly lateral in position.

248. To Prof. Owen is chiefly due the credit of developing, though not of originating, the view that the bony skeletons of all vertebrates are founded upon one plan, termed the typical skeleton: opinions differ considerably as to details.

Besides the endo-skeleton, neuro-skeleton, or true bony skeleton, there also exists (A) an exo-skeleton or dermo-

FIG. 426.



Theoretical section of an embryo. Showing relative position of various systems.
b body-wall. *sp* splanchno-spinal system. *s* sympathetic system. *a* alimentary canal. *h* hæmal system.

FIG. 427.

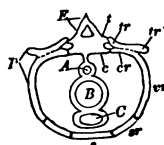


Diagram of typical skeletal section.
According to Mivart.

A, B, C parts of the hypaxial system relating *A* to great vessels, *B* alimentary tube, and *C* heart. *E* epaxial parts. *P* paraxial parts. *c, t* capitular and tubercular process. *cr, tr, tr'* capitular and tubercular parts of rib. *vr* vertebral rib. *sr* sternal rib. *s* sternum.

skeleton, very probably only represented by the teeth, nails, and hair; (B) a splanchno-skeleton, and (C) a sclero-skeleton. According to Mivart the skeletal elements may be thus classified:—

A. Axial skeleton	{	Central or axial	{	Vertebral centra.
		Epaxial		Neural spines.
				Neural arches.
		Paraxial		Diapophyses—upper ribs (united to the lower in man).
				Parapophyses—lower ribs and sternum.
		Hypaxial		Hypapophyses, absent in man.
B. Appendicular skeleton	{	{	Splanchnapophyses, cranial visceral arches.	
			Ventral boundary of heart sac, never ossified.	
			Pectoral girdle and fore-limbs.	
			Pelvic girdle and hind-limbs.	

The other elements he classifies as ecderonic and enderonic appendages; nails and hair belong to the former, teeth to the latter.

The great majority of anatomists believe that the skull arises from four very much modified typical vertebræ (some say three). The notochord terminates at the base of the skull in a cartilaginous plate, the investing mass of Rathke, from which spring theoretically four chief pairs of processes, which, according to Owen, become the hæmal or visceral arches:—

in front to form the ethmoid, pre-sphenoid, nasal, and pre-maxillary portions of the skull. Beneath the trabeculae are the 2nd pre-oral pair (or 1st arch): they form the

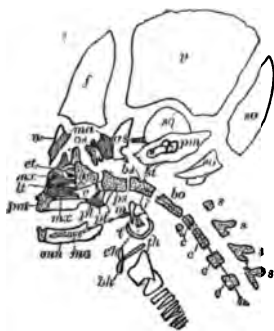
FIG. 429.

*Side view of fetal skull elements.*

A side view. 1 trabeculae. 2 pterygo-palatine processes. 2' maxillary process. 3, 4, 5, 6 post-oral processes (3 mandibular, 4 hyoidean). *o* optic vesicle. *a* auditory capsule. *m* mouth. *b* the five branchial clefts. (*e* the tympano-Eustachian passage.) A' view from beneath of the same. Figs. as before. *n* notochord surrounded by *io* investing mass. *p* pituitary fossa.

pterygoid and palatine bones: belonging to and on the outer side of each is a process, which becomes the superior maxillary and malar bones. Then come the post-oral processes: the 1st pair (2nd arch) become the mandible, or

FIG. 430.

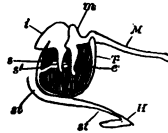
*Bones of fetus at birth. (After Allen Thompson.)*

f frontal. *p* parietal. *so* supra-occipital. *eo* ex-occipital. *bo* basi-occipital. *pm* petro-mastoid. *st* styloid process. *sq* squamoso-temporal. *as* ali-sphenoid. *ma* malar. *os* orbito-sphenoid. *ps* pre-sphenoid. *n* nasal. *l* lachrymal. *mx*, *mx* superior maxillary. *pm* pre-maxillary. *lt* lower turbinal. *et* ethmo-turbinal. *me* median ethmoid. *v* vomer. *p* palatine. *pt* pterygoid processes. *mn* mandible. *mc* Meckel's cartilage. *m* malleus. *i* incus. *t* tympanic bone. *ch* cornicula, or cerato-hyals. *th* cornua, or thyro-hyals. *ba* body of the hyoid or basi-hyal. *c*, *c* centra of first four cervical vertebrae. *s*, *s* their neural spines. *n* notochord.

inferior maxillary, and the malleus (= os quadratum of the sauropsida): the cartilaginous base of this arch is the cartilage of Meckel; then comes (rather above) the auditory pit: the 2nd pair, or hyoidean arch, becomes the styloid process, hyoidean cornicula, and incus—the stapes being an outgrowth from the tympanic wall: the 3rd pair, or thyro-hyoidean arch, becomes the cornua and body of the hyoid: the 4th pair is not permanently represented. Each arch—

perhaps excepting the trabeculæ—may be considered as belonging to a vertebra. These processes or arches are

FIG. 431.

*Development of the ear.*

T tympanic bone. *e* orifice of Eustachian tube. *M* Meckel's cartilage. *m* malleus. *i* incus. *s* stapes. *st* styloid process. *stl* styloid ligament. *H* hyoid bone.

generally called the cranio-visceral, pharyngeal, or branchial arches. In fish, the cartilaginous and arterial branchial arches become the gills (branchiæ). The fifth branchial arch is only represented arterially in man. Behind the arches are the four branchial clefts, the first of which becomes the tympanic cavity and Eustachian tube, but the others are soon obliterated. All the bones of the trunk and limbs arise from cartilage, excepting part of the clavicle and the smaller sesamoid bones.

249. When the ovum enters the uterus, the mucous membrane of the latter becomes thickened and spongy, and as this, for the greater part of its thickness, becomes cast off at birth, it is termed the decidua. The decidua lines the whole interior of the uterus, and at the place where the ovum is in contact with it—on the posterior wall, it rises up and invests it: the cavity lining is termed the decidua vera, the embryonic coat the d. reflexa, the united part the d. serotina. The space between the d. vera and d. reflexa is at first filled with fluid, but afterwards these two layers become indistinguishably united, and are cast off at birth. Since the yolk of the human ovum (like that of most other mammals) is very small, it affords nutriment to the embryo for a very short time only, hence the necessity of a maternal supply, and therefore the placenta. At first the villi of the chorion are limited to a broad marginal zone, then cover the whole, finally disappearing except at the d. serotina, where they become greatly developed. As the chorion sends out its villi, which it does upon entering the uterus, the d.

FIG. 432.

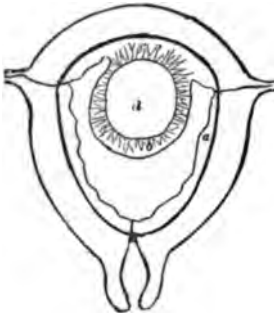
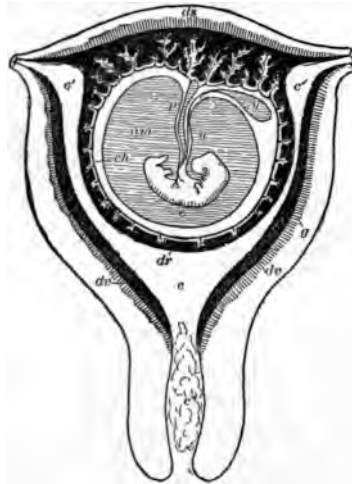


Diagram of uterus showing decidua.
a decidua vera. *b* decidua reflexa.
c decidua serotina. *d* embryonic
 cavity, from surface of which
 project villi.

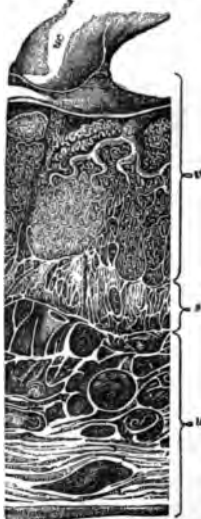
FIG. 433.



*Theoretical diagrammatic section of the uterus at
 50th day of pregnancy.*

c cavity of the uterus which becomes the
 cavity of the decidua. *c'*, *c'* cornua.
e'' cervix, plugged with mucus. *de* de-
 cidua vera. *dr* decidua serotina. *dr* de-
 cidua reflexa. *e* embryo. *am* amnion.
y yolk vesicle. *ch* (allantoid) chorion.
u umbilical cord. *p* remains of allantois
 pedicle with the umbilical vessels. *g* ute-
 rine glands. (The placenta is shown as if
 on the fundus instead of on the posterior
 wall of the uterus.)

FIG. 434.



*Vertical section through placenta and wall
 of uterus. (After Wagner and Farre.)*

u wall of uterus with numerous sinuses,
 some containing coiled arteries. *s* de-
 cidua serotina. *v* tufts of foetal vas-
 cular villi. *uc* umbilical cord.

FIG. 435.

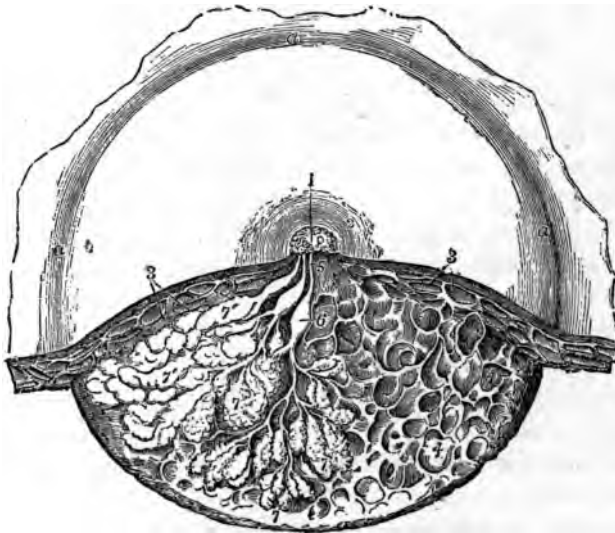


Extremity of a foetal tuft.

reflexa and d. serotina also develop vascular processes, which interlock with the embryonic villi: the little hollows into which the villi depend are termed sinuses; they are maternal venous spaces, filled with maternal blood, supplied by coiled 'curling' arteries; developmentally, the sinuses are capillary enlargements. The embryo is not connected directly with the blood, but there is always a delicate double wall of its own interposed; and besides, there is at most, if not all parts, a layer of maternal decidua-cells, and a basement membrane derived from the enlarged uterine vessels, so that the blood is communicated by endosmosis and exosmosis. The vessels of the chorion villi, like the villi themselves, after a time wither away, except where the chorion is attached to the d. serotina, where they become more highly developed, and last till birth—the chorion and d. serotina becoming united, and forming a membrane termed the *placenta*. The human placenta is a circular disc of about 8 in. diam., when fully developed: (it is deciduary).

250. After birth the child is for a time supplied with nutriment by a maternal product—*milk*, which is secreted

FIG. 436.



Female mamma during lactation. (Luschka.) 3. (The lower portion dissected.)
 a, a border of mamma. 1 mamilla. 2 areola. 3 adipose tissue. 4 loculi in which the
 glandular lobules lie. 5 three lactiferous ducts. 6 ampullae. 7 glandular lobules,
 at 7' unravelled.

by the *mammæ*, or mammary glands, two in number, situated on the breast, one upon either side: (the nipple is opposite the space between the fourth and fifth ribs). They are always very small and rudimentary in the male, and except during lactation their glandular structure is not readily recognizable in the female: the glandular elements seem to spread and develop during pregnancy: they arise from scattered centres in the matrix, and not from epidermic involution. They are convex discs (slightly elliptical horizontally), about $4\frac{1}{2}$ in. diam. by 2 in. in thickness, and are embedded in areolar tissue, containing a little non-striated also: the left is rather the larger. In the male they measure about $\frac{1}{2}$ in. by $\frac{1}{8}$ in. The nipple is sub-central in position, being rather to the outer side. They are (when developed) compound vesicular glands, and possess secretory capillaries. Both vesicles and ducts have a columnar epithelium. The tubes from the minute lobules unite to form about 15 (10—25) ducts, the galactophorous or lactiferous ducts,

FIG. 437.



Galactophorous ducts with their lobules.

FIG. 438.

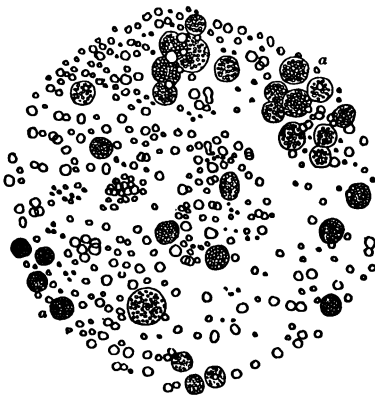


A milk lobule (more highly magnified).

which convey the milk to each mammilla or nipple, opening at its end by minute contracted orifices; before entering the nipple and beneath the areolæ they become dilated into reservoirs—ampullæ or sinuses. The nipple contains much contractile tissue, and has its epidermis coloured, as also is the epidermis of a space around it—the areola, which in light-haired virgins is pink,—dark-coloured in dark-haired and pregnant persons, and in those who have borne children, being darkest during lactation. The areola contains contractile tissue. *Milk* contains all the articles of nutriment which are for some time required. It is a watery fluid, in which float numerous oily or fatty globules, which give it its whitish appearance, and from which butter is formed. The oil, i. e. butter-globules, are of various sizes. The

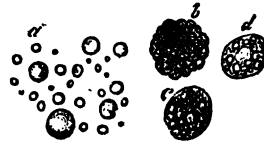
milk of the first few days after parturition is termed colostrum, and contains large granular-looking cells—colostrum-corpuscles, consisting of minute oil globules contained in an envelope or cell-wall: they are detached and modified glandular cells. Human milk ordinarily consists of water 884 (861—914), casein and albumen 32 (9—55), butter

FIG. 439.

*Human milk.*

Numerous colostrum corpuscles *a* are seen among the milk-globules.

FIG. 440.

*Milk. (Kölliker.)*

a, *a* milk-globules. *b*, *c*, *d* colostrum corpuscles.

30 (8—54), sugar of milk 52 (35—68), salts 2+; sp. g. about 1.031. Before parturition the albumen predominates much over the casein,—the reverse obtains afterwards, but the proportion of these depends chiefly upon the method of examination. The younger the person the richer the milk—less water (but also less sugar). During lactation, unless much prolonged, menstruation is generally suspended.

251. The period of gestation in the human being is generally about 280 days from the last period of menstruation, and is rather longer with a male than a female child. Parturition is the result of a kind of peristaltic action of the uterus, aided, after that the head (which appears first) begins to be expelled, by reflex action of the expiratory and abdominal muscles, as in defæcation. The number of young is generally one: there are twins in about .11 cases; 3 or more, once in 1000. True twins are developed from separate ova, false twins (e. g. the Siamese) from one ovum. A

foetus of three months measures $2\frac{1}{2}$ in., weighs $1\frac{1}{2}$ oz.; of six months, 10 in., 1 lb. An infant at birth weighs about $6\frac{3}{4}$ lbs. ($7\frac{1}{4}$ male, $6\frac{1}{4}$ female): height 20 in. male, 19 female. As compared with the adult, the brain is very large, the limbs small, and many of the viscera have different relative sizes. The following is a table of some of the relative weights:—

	Fœtus at term.	Adult.
Body	1000	1000
Encephalon	148	23
Liver	37	29
Heart	7·8	4·2
Kidneys	6	4
Supra-renal capsules	1·6	·13
Thyroid	·6	·5
Thymus	3	·3

There are 104 male to 100 female children (in England). The cause of sex is unknown, but it has been observed that if the husband be older than the wife, though only by a year, male children predominate, if of the same age or younger, female children do so: the older the father, the more chance of a son, and *vice versâ*. Also, if impregnation occur at (or near) the beginning of the 'catamenial-' or menstrual-period, the offspring will generally be female,—if at (or near) the close, male,—the ovum being more advanced in the latter case. Deficient alimentation may be a cause; thus, in a poor or mountainous country there are more male children relatively. It has been suggested that as the sex only displays itself at a late period, the influence may rest with (something in the blood of) the mother!

It will be needless to discuss the differences of the two sexes, mentally and physically, e. g. the greater endurance and strength (as 9:5, on an average) of the male; the changes (of voice, amount of hair and of adipose tissue, *emotions*, &c.) which take place at puberty, &c. But we should not ignore the very strong tendency to transmit hereditarily (to offspring) mental and physical peculiarities and *predispositions* (even to diseases), sometimes skipping a generation or so (Atavism).

252. Developmentally, the foetal stages of the higher animals are often the permanent ones of lower animals, and

very slight traces of the foetal structures remain permanent, and are to be seen more or less distinctly in the adult: generally speaking, the more specialized are the functions, and so the more developed the structures, the higher is the animal. Man is, upon the whole, the most highly developed

FIG. 441.



with respect to specialization, especially his brain; and this, aided by such a mechanical instrument as the hand, gives him a vast superiority over other animated beings. As an animal, man is a Vertebrate of the Class Mammalia, Order Bimana. The characteristics of the order may be summed up as: Brain archencephalous (the cerebrum very much convoluted; and viewed from above, hiding the rest): Feet plantigrade (Walking [erect] natural mode of progression): Pollex opposable, Hallux not so: Clavicles present: Nails on

the digits, which are five in number to each of the four limbs: Teeth, inc. $\frac{2-2}{2-2}$, c. $\frac{1-1}{1-1}$, pm. $\frac{2-2}{2-2}$, m. $\frac{3-3}{3-3}$: Testes lodged in a permanent scrotum: Mammæ, two in number, pectoral in position: Placenta, discoidal deciduary. Man is omnivorous; originally frugivorous probably: the teeth are evenly developed, neither kind predominating. The period of infancy is relatively *very* long,—growth slow, and puberty late.

253. Life cannot be accurately defined,—or easily, unless negatively as the sum total of forces which resist death. Life is dependent for its origin, or rather its origin is connected with, bioplasm, an *apparently* unorganized protoplasmatic (albuminoid) substance, so that organism, as such, seems to be dependent upon life rather than life dependent on it, though the dependence is probably, in some manner, mutual. Life is supported by the potential energy or latent force of the food being converted into kinetic energy, or active force, displayed in the various expressions of 'vital force' (a term of convenience). Oxygen seems to be the great vitalizing agent; and oxidizable phosphorus the initiator of oxidation. All the particles of the body are constantly changing, from the commencement of life till its termination,—each atom seeming to be of use to life for a very limited time only. The various elements combine into proximate principles, decompose and recombine several times into others, just as their representative factors in the algebraical terms of the chemical formulæ. Thus there is always going on a series of assimilative integrations, and of disintegrative eliminations. Starches are converted into saccharoses, and these again into glucoses,* prior to absorption; the other organic substances similarly undergo preparatory changes: we next find them as comparatively undifferentiated principles in the blood, there changing

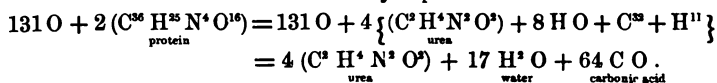
- | | | |
|----------|-----------------|--|
| * Oxygen | 10. Starches | { Starch, dextrin.
Glycogen. |
| " | 11. Saccharoses | { Saccharose (cane-sugar).
Lactose, milk-s. |
| " | 12. Glucoses | { Dextrose (grape-s).
Inosite, galactose. |

slightly, then being drawn off, and specialized as higher forms, frequently being again returned to the circulation to be partly re-used; finally, when of no further (direct) use to the economy, to be secreted or excreted, as the case may be. Blood, as the fluid medium, necessarily contains very frequently much useless matter for a short time, e. g. surplus water. Some of the changes have been very slightly noticed in the case of digestion and assimilation,—those of disassimilation are mostly very obscure. The nitrogenous elements become converted into urea,* &c., the non-nitrogenous into carbonic acid and water, the mineral elements are also (mostly) oxidised. About a ton per annum is used in the support of life.

The functional activity of the various parts of the body may be represented by a wave, which rises suddenly, falls gradually; there is very often a slight secondary wave on the descent. The body displays several periodical changes, which are more or less marked, and may all be represented by waves: (1) Life; infancy and youth, adult life, senescence; viability: (2) Annual; slightly affects the body generally, rising in spring, falling in autumn; N.B., weight, pulse (fecundity is rather greater in spring): (3) monthly; menstruation: (4) daily; general—*sleep*, pulse-rate, oxygen and carbonic acid curves: (6) part-days; secretion of the various digestive fluids; electric tides: (7) momentary; curves of pulse, respiration, nerve- and muscle- currents. Alterations may be induced by Sabbath rests, nocturnal labour, &c.

254. The vital powers, as regards duration of life (i. e. viability) are greatest at 13, but are really stronger,—the constitution being more solid, and capable of greater endurance about 35, as may be seen by the vital capacity, pulse, &c., although the body is fully developed practically at about 24 in the male, and 20 in the female. The descending part of the curve of viability differs very slightly in

* The formation of urea was formerly expressed thus:



the two sexes. The average duration of human life is, in England, nearly 45 years (annual death-rate, 22·3 per 1000) : it is slightly greater in the female than in the male sex ; in rural than urban life (being very nearly 54½ and 43 years respectively) ; &c.

255. Death is the cessation of the vital powers. The exact moment of its occurrence is not scientifically known, since life depends upon the action of numerous systems, and sometimes one, sometimes another of these fail in function first at death. The cessation of the heart's beating is about the most satisfactory indication, for upon the circulation chiefly depends the performance of all the other functions ; the cessation of consciousness is not so easily determined, though this would be a far more proper test. Immediately after real death the body begins to putrify—become disorganized. Apparent death, as in trances, may last for a long time, and also partial apparent death, as when a person is stunned or faints,—the disorganization, if it can be said to have commenced, not progressing to a sufficient degree to hinder restoration. Parts may be altered in function, and finally in (visible) structure, by disease or injury, but the effects by no means necessarily or even usually cause death. Thus the body exhibits cyclical and periodical changes, and is ever a scene of change, and of movements, both molecular and general, until death finally puts an end to this wonderful series of phenomena, and the dust returns to the earth, and the spirit to God who gave it.

THE END.

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